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THE PN-7 BOAT SEAPLANE.

DESCRIPTION AND PERFORMANCE.

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HISTORICAL DATA.

Until the development of the PN-7, the F-5-L was the last design in the boat seaplane class. The F-5-L is a boat seaplane having two Liberty engines. The PN-7 is a boat seaplane using the hull of the F-5-L, a much cleaner wing construction with high-lift wings, and two Wright T-2 engines. As the designation shows, the PN-7 is a patrol plane designed by the Navy and the seventh in the series of Patrol types. It

* Plane Performance Curves and Data from Bureau of Aeronautics' Technical Note No. 132 by Lieut. Walter S. Diehl (CC), U.S.N.

was built at the Naval Aircraft Factory, Philadelphia, flight-tested at that place, and operated in service by the Aircraft Squadrons, Scouting Fleet during the joint fleet exercises of the winter of 1923-24.

GENERAL.

The PN-7 is a twin motored boat seaplane having a designed gross load of 14,800 pounds, a maximum speed of 105 miles per hour, a stalling speed of 58.2 miles per hour, a service ceiling of 8000 feet, and a climb in ten minutes of 4300 feet. The propelling machinery consists of Wright T-2 engines built by the Wright Aeronautical Corporation of Paterson, N. J., and rated at 525 H.P. at 1800 R.P.M.

General Dimensions:

Length overall, feet and inches	49–0 11/16
Height overall, feet and inches	18–1 1/4
Span upper wings, feet and inches	72–10
Span lower wings, feet and inches	72–10
Chord (both wings), feet and inches	9–0
Gap, feet and inches	9–4
Incidence (both wings), degrees	2
Stagger	None
Dihedral (lower wing only), degrees	3
Wing section	USA–27
Area of upper wings (including ailerons), square feet	675
Area of lower wings, square feet	545
Total wing area, square feet	1220
Ailerons (total area), square feet	120
Stabilizer, square feet	121
Elevator, square feet	55
Fin, square feet	54
Rudder, square feet	42

Engines (2) Wright T–2, 525 B. H. P. at 1800 R. P. M.
Propellers.....D=10 feet 6 inches, P=5 feet 6 inches.
C. G. Location: variable with load, from 32 per cent to 34 per cent of mean chord.
Normal stabilizer setting 0 degree to thrust line.

Conditions of Loading:—The conditions of loading ready for service in every respect, with full complement of officers

and crew with their effects and consumable load is tabulated below for two conditions of operation, bombing and patrol.

Weight.	*Bomber.*	*Patrol.*
Dead load	9850	9850
Crew (4)	720	720
Fuel	2046	2857
Oil	194	194
Flexible guns, etc.	265	265
Bombs	1065	0
Radio and accessories	285	285
Navigational equipment	35	35
Miscellaneous	210	210
Gross load	14,670	14,416
Pounds per square feet	12.02	11.82
Pounds per B. H. P.	13.97	13.73

Complement:—The complement consists of four men; the first pilot, the relief pilot, a mechanic-gunner, and radio operator.

Armament:—The armament consists of: 4 Lewis guns, 12 Lewis gun-97-round ammunition boxes, and 1 Colt revolver with 28 rounds of ammunition; 1 bomb sight, 4 bomb gears and bombs of type prescribed.

Anchor Gear:—The anchor gear consists of one 80-pound anchor and about 25 fathoms of lime. These are to be carried only when necessary.

Fuel Stowage:—The total gasoline capacity is 489 gallons and the fuel is stowed in five tanks. One hand gas pump and two windmill pumps are fitted. These deliver gasoline from the tanks to a gravity tank in the center section of the upper wing whence it flows by gravity to the carburetors and, through a sight-feed glass in the overflow line, back to the tanks. The total lubricating oil capacity of 30 gallons is carried in two tanks, one in rear of each engine.

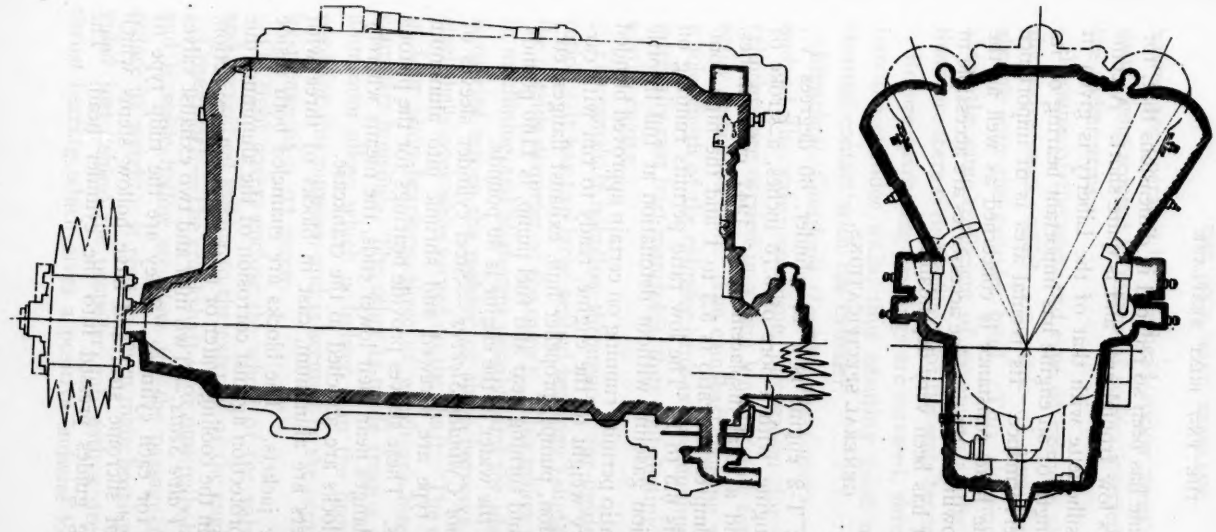
Communication Equipment:—The following communication equipment is installed: One radio set with directional compass; one inter-communicating set; 1 Aldis lamp; 1 Very pistol and ammunition; hand semaphore flags.

Navigating Equipment:—The following navigation equipment is installed: Drift indicator; compass with azimuth circle; chart board and charts; sextant; torpedo boat watch; universal drafting machine; instrument case and navigation books.

Miscellaneous:—Miscellaneous equipment is provided as follows: Bilge pump; discharge and suction hose with strainer; hand fire extinguishers and pressure Pyrene; tool kit; canvas bucket; first aid kit; parachutes; life jackets and emergency rations.

DESCRIPTION POWER PLANT.

The power plant consists of two Wright T-2 aeronautical engines having each a rated output of 525 H.P. at 1800 R.P.M. These engines were designed and built by the Wright Aeronautical Corporation under the general supervision of and in collaboration with the Material Division of the Bureau of Aeronautics. There are a number of noteworthy features. The engines have a guaranteed rating of 525 H.P. at 1800 R.P.M. and of 650 H.P. at 2000 R.P.M. The first rating is for a normal compression engine 5.3 to 1 and the second for high compression 6.5 to 1. The average full throttle power is 550 for the first condition and 680 for the second. In an experimental model of a racing engine the engine developed 750 H.P. at 2200 R.P.M. This was accomplished on a dry engine weight of 1160 pounds. The rated weight per H.P. is therefore 2.21 pounds. The Liberty engine on a rating of 410 H.P. gives a weight per H.P. of 2.12. On a rating of 680 H.P. at 2000 R.P.M. the weight of the Wright engine becomes 1.7 pounds per B.H.P., which is a very low figure. The engine has a guaranteed fuel consumption of .52 pound per H.P. hour and an oil consumption of .025 pound per H.P. hour. These are approximately the guarantees for the Liberty but the Wright has actually gone as low as .47 pound of fuel and .0065 pound of oil per H.P. hour. This specific fuel consumption was at nine-tenths power.



SKETCH SHOWING WRIGHT MODEL T-2 ENGINE SUPERIMPOSED ON THE LIBERTY 12.

FIG. 1.

THE SHADED OUTLINE IS THAT OF THE T-2.

The T-2 engine has been so reduced in dimensions that, for its power, it has low frontal area and is quite short. A comparison of its silhouette with that of the Liberty is given in Fig. 1. The length of an engine has important bearing on its stiffness and performance. Its frontal area is of importance in so far as the head resistance is concerned as well as the difficulties of cowling. The engine accessories are accessible in this engine. It has been very dependable.

GENERAL SPECIFICATIONS.

The Wright T-2 engine is a 12-cylinder, 60 degrees V., water-cooled engine, with a bore of 5.75 inches, a stroke of 6.25 inches and a total displacement of 1947 cubic inches. The normal compression ratio is 5.3 to 1 and the high compression ratio is 6.5 to 1. The low ratio permits running on domestic aviation gasoline without detonation at full throttle and the high ratio permits running on certain approved blended fuels. The dry weight of the engine, ready to run with carburetors, ignition, pumps, propeller hub, exhaust flanges, etc., but without hand turning gear and fuel pump, is 1160 pounds. The weight of the water in the engine is 59 pounds.

Cylinders and Cylinder Sleeves:—Steel cylinder sleeves of the open end type are screwed and shrunk into aluminum cylinder blocks. These sleeves provide bearings for the pistons and through flanges near their lower ends, the means whereby the cylinder blocks are attached to the crankcase.

The cylinders are aluminum, cast in blocks of three with integral water jackets. The blocks are enameled both inside and out as a protection against corrosion of the aluminum due to impurities in the cooling water or to the atmospheric action.

Valves and Valve Seats:—Two inlet and two exhaust valves are provided for each cylinder. They are the tulip type of valve made of silcrome steel and have hollow stems which work in long guides pressed into the cylinder head. The

valves are operated by overhead rocker arms, tappet adjustment being secured by means of screws inserted in the ends of the rocker arms.

Because of the open end type of cylinder sleeve employed, the valve seats, which are made of aluminum bronze, are shrunk into the cylinder head. This aluminum bronze has about the same coefficient of expansion as the aluminum and therefore there is no likelihood of the seats becoming loose.

Bronze spark plug bushings are screwed, shrunk and pinned into the cylinder walls, thus assuring good mechanical and thermal contact with the cylinder.

Camshaft, Camshaft Housing and Covers:—The camshaft and all the valve operating mechanism for each bank of cylinders are carried in a cam housing and form a complete, easily detachable unit. The camshaft housing which runs the whole length of the cylinder bank is an aluminum-casting with integrally cast inlet manifolds, thus contributing to the rigidity of the engine.

The camshaft is hollow throughout, for lightness and lubrication. It has two large central bearings (slightly larger than the outside diameter of the cams). This makes great accuracy in machining and alignment possible and the idea of lightness is carried out in the making of these bearings, by shrinking steel shells over webs turned on the shaft. The camshaft runs in four plain bearings, three of which are integral with the camshaft housing. The other is made from a special copper aluminum alloy, which is lighter than the bronze ordinarily used for this purpose, and is secured in the camshaft housing by means of a set screw.

Oil tight covers enclose the whole of the valve mechanism and prevent oil leaking to the exterior of the engine.

Crankshaft:—The crankshaft is of unusually large diameter and is made hollow to allow for the passage of oil and to reduce its weight. It runs in seven main bearings and is provided just behind the propeller hub with a deep row radial thrust bearing which gives a positive endwise location to the

shaft. The propeller end has seventeen splines, the space in which the eighteenth would come being left blank to make sure that the hub is always placed on the shaft in the same position. These splines are intended to take torque only, the axial position and centering of the hub being determined by two cones, one at each end of the splines. The plugs which seal the holes in the crankthrows are easily removable to facilitate cleaning.

Connecting Rods:—There are two connecting rods to each crankpin, an inner and an outer. Both are tubular. The inner rod is forked at the large end and embodies a new feature in the type of bearing used. This bearing is a split sleeve about ⅜ inch thick cast from a special copper-tin-lead alloy which requires no babbitt and will not seize on the crankpins even in the event of total failure of the lubrication system. The bearing is ground on the outside, in the space between the fork of the inner rod, to form a bearing for the outer rod.

Pistons and Piston Pins:—The pistons are made of aluminum alloy and are simple in design. No ribbing is employed under the head, as the section is amply strong without and heavy enough to dissipate heat from the center of the head rapidly. Each piston has four compression rings near the head and one scraper ring in the skirt.

The piston pins are free to turn in both the piston pin bosses and the small ends of the connecting rods. Bronze plugs are driven into the ends of the pins to remove the possibility of scratching the walls of the cylinder. (The T-3 engine has Duralumin plugs.)

Crankcase:—The crankcase is composed of two aluminum castings joined below the center line of the crankshaft. The sections are rather heavy and well ribbed for rigidity. All the bearings are carried in the upper half of the case, the bearing caps being made of forged duralumin. The lower half of the case is a sump from which oil is pumped as rapidly as it is thrown off by the bearings and cylinders. This construction makes the bearings very accessible after removing the lower half of the crankcase.

Vertical Shaft, Camshaft Drive Shaft:—In the upper half of the crankcase at the rear end is a vertical shaft which is driven from a bevel gear on the crankshaft. This vertical shaft in turn drives the inclined shafts running to the camshafts, two synchronizers, the magneto drives and the fuel pump.

The inclined shafts, or camshaft drive shafts, as they are called, have serrated couplings near their upper ends to facilitate timing of the engine.

Magneto Drive, Magneto Coupling:—There are two Splitdorf magnetos, each 12-cylinder instruments. One is wired to all spark plugs located on the outside of the cylinders and the other to all plugs situated in the Vee between the blocks. The magnetos are mounted horizontally and crosswise with their distributor boxes towards the outside of the engine.

The magneto couplings used differ on the T-2 and the T-3 engines. The T-2 coupling is the solid gear drive. The T-3 coupling is composed of two halves joined together with a thermoid disc. Adjustment of the spark is obtained through a little worm and worm wheel in the half of the coupling attached to the armature shaft, and provision is made for locking the adjustment when it has been set. Great accuracy in the magneto timing is possible by this means and once it is set there is no chance of accidental alteration of the timing.

Lubrication Oil Pumps:—The lubricating system is operated by three pumps which form a single assembly. Two of these are suction pumps which draw oil from the front and rear of the crankcase, respectively, and deliver it to the external oil tank. The third is a pressure pump which delivers oil through a tubular strainer arranged transversely in the lower half of the crankcase, to an oil manifold bolted to the bearing caps, from which it is distributed to all crankshaft bearings.

Oil is supplied to the center of the camshaft housing by means of two copper pipes, leading from an annular passage around the center main bearing. The center bearings in the housings are drilled in such a way as to distribute the oil supply

to the bore of the rocker arm shafts and the rocker arms and cam surfaces are lubricated by the oil forced through small holes in the rocker arms. The camshaft bearings are lubricated through drilled passages which connect the bearing surfaces with the rocker arm shaft bores. Oil holes are drilled in the rear camshaft bearing and the oil which lubricates this bearing is allowed to force its way into the bore of the camshaft, through holes drilled in the shaft. It then flows out through holes in the tachometer shaft and returns to the sump by gravity, oiling in its downward path, the camshaft drive shaft, gears and bearings. The surplus oil in the camshaft housing returns to the sump through pipes, located one at each lower corner of each housing.

The pistons and wrist pins are lubricated by splash from the crankpins. The pressure employed in the lubrication system is controlled by a relief valve located in one end of the oil strainer.

Water Pump:—Below the oil pump and driven from the same shaft is a water pump with two outlets which deliver water to the base of each of the four cylinder blocks. The pump is of the centrifugal type.

Gasoline Supply Fuel Pump:—Gasoline is supplied to two Stromberg NA-U6T carburetors, located in the Vee of the engine, by means of a Wright-Viking fuel pump. Both carburetors are attached to an aluminum air horn which can be removed with the carburetors and their control levers as a single assembly.

The Wright-Viking fuel pump consists of a bronze body in which runs a steel gear with teeth cut internally; this is driven by the pump drive gear which meshes with a bevel gear on the vertical shaft. The internal gear drives another small bronze or fiber gear which runs on a shaft offset from the center line of the internal gear. The gasoline drawn in by the pump is carried round the pump in the pockets formed by the spaces between the teeth of the internal gear and it is delivered in a constant stream to the outlet nipple. Carried in a boss in

the pump cover is a relief valve. This consists of a bronze plunger which is held on its seat in the cover by a helical spring. The pressure of this spring can be adjusted by means of the adjusting screw so that the valve will open and allow surplus gasoline to flow through the relief line to the gasoline tank, when the working pressure is exceeded.

DISCUSSION.

It is interesting to compare the Wright T-2 with the Liberty engine in several important features of design. The difference at once apparent is the cleanness of the new design. Comparing the end views, Figs. 2 and 3, with particular attention to cylinder construction, we find in the Liberty the individual cylinder construction with welded sheet metal water jacket and the valve seats integral with the cylinder. In the T-2 we find a steel sleeve screwed and shrunk into an aluminum head. The aluminum head carries the water jacket and valve seats. These are two radically different principles of construction. A third method is found in the Packard 1500, a new engine being developed under the supervision of the Navy, in which the individual steel cylinder design is used for the valve seats and below while the aluminum casting carries the inlet and exhaust passages and ties the cylinders together.

Both the T-2 and Liberty have the valves in the head but the T-2 provides two exhaust and two inlet valves per cylinder against the Liberty's one. The T-2 cylinders are cast in blocks of three, these blocks being tied together by a cast aluminum camshaft housing which runs the whole length of the bank and contributes to the rigidity of the engine. The intake manifolds are cast integral with the housing. The individual Liberty cylinders are tied together by an aluminum camshaft housing which carries only the camshaft and is hardly sufficiently rigid to tie the cylinders together satisfactorily without damage to itself. The Liberty spark plugs are in the head but are so near the cylinder walls as to be no nearer the center of the cylinder

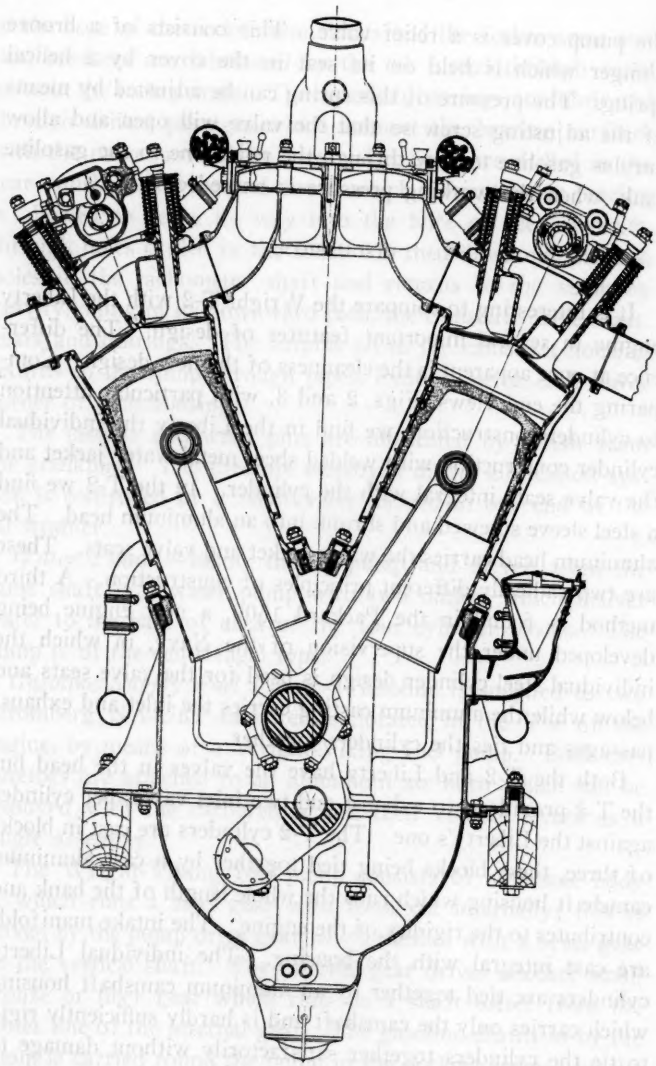
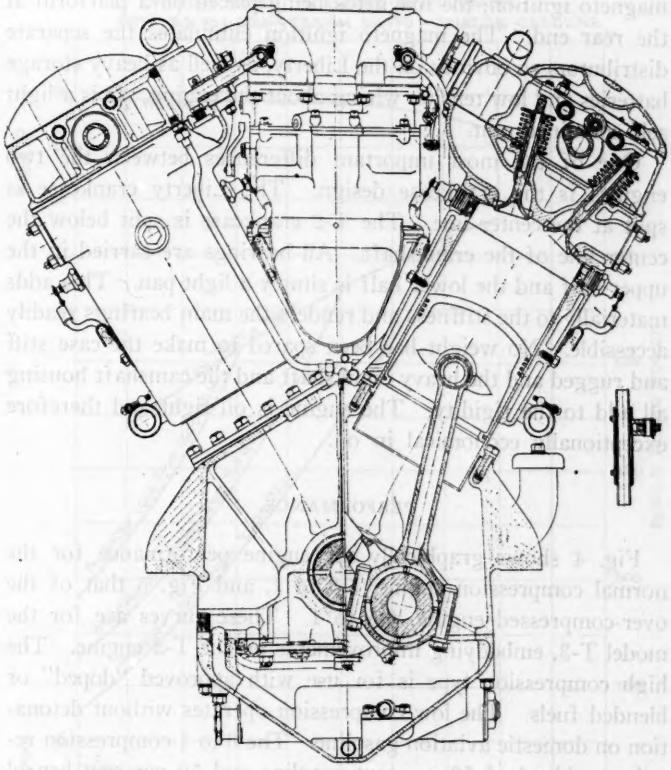


FIG. 2.
TRANSVERSE SECTION THROUGH CYLINDERS OF LIBERTY ENGINE



Assembly Drawing
WRIGHT
Model T-2 Engine
(Transverse Section)

FIG. 3.

than the T-2 plugs which are in the sides and therefore much more accessible. The Liberty has battery-generator ignition, the generator standing on end in the Vee. The T-2 has double magneto ignition, the magnetos being placed on a platform at the rear end. The magneto ignition eliminates the separate distributors so obvious on the Liberty, as well as heavy storage batteries and low tension wiring about the engine. It is a light self-contained unit.

One of the most important differences between the two engines is the crankcase design. The Liberty crankcase is split at the center line. The T-2 crankcase is split below the center line of the crankshaft. All bearings are carried in the upper half and the lower half is simply a light pan. This adds materially to the stiffness and renders the main bearings readily accessible. No weight has been spared to make the case stiff and rugged and the heavy crankshaft and the camshaft housing all add to the rigidity. The engine is oil tight and therefore exceptionally economical in oil.

PERFORMANCE.

Fig. 4 shows graphically the engine performance for the normal compression engine, 5.3 to 1, and Fig. 5 that of the over-compressed engine, 6.5 to 1. These curves are for the model T-3, embodying improvements on the T-2 engine. The high compression type is for use with approved "doped" or blended fuels. The low compression operates without detonation on domestic aviation gasoline. The 6 to 1 compression requires a blend of 50 per cent gasoline and 50 per cent benzol or its equivalent. The 6.5 engine requires at least 65 per cent benzol and 35 per cent gasoline or its equivalent. A glance at the performance curves shows a flat full throttle curve without appreciable falling off at high speeds. In the Liberty there is a peak at 1900 R.P.M. The T-2 therefore lends itself to gearing and is particularly adapted to work in heavy boats where a burst of power is required for taking off. Thus

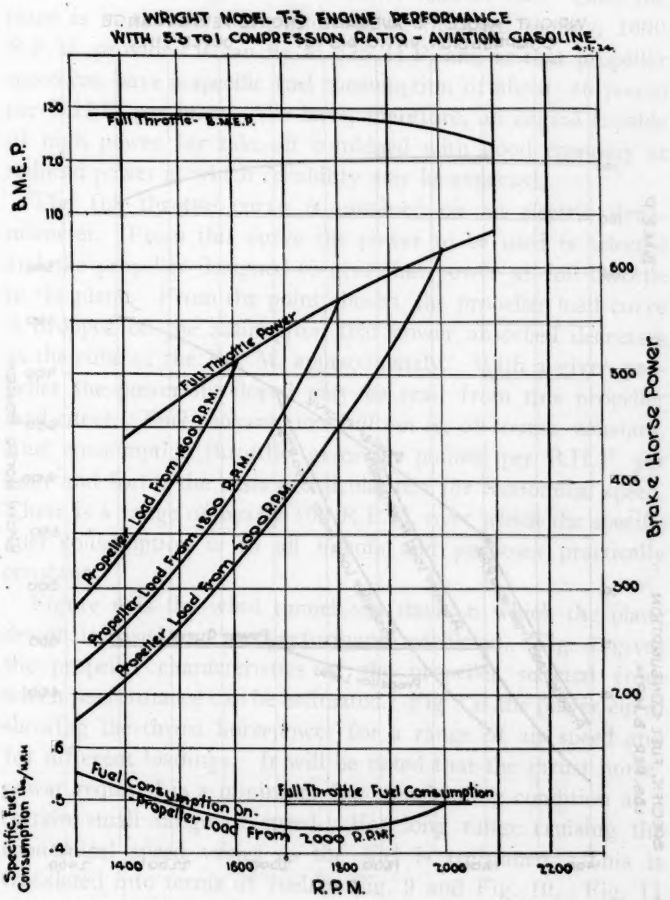

WRIGHT MODEL T-3 ENGINE PERFORMANCE
WITH 5.3 TO 1 COMPRESSION RATIO - AVIATION GASOLINE.
B.M.E.P.
130
120
110
Full Throttle- B.M.E.P.
Full Throttle Power
Propeller Load From 1600 R.P.M.
Propeller Load From 1800 R.P.M.
Propeller Load From 2000 R.P.M.
600
500
400
300
200
Brake Horse Power
.6
.5
.4
Specific Fuel Consumption Lbs/B.H.P.
Fuel Consumption On Propeller Load From 2000 R.P.M.
Full Throttle Fuel Consumption
1400
1600
1800
2000
2200
R.P.M.

FIG. 4.

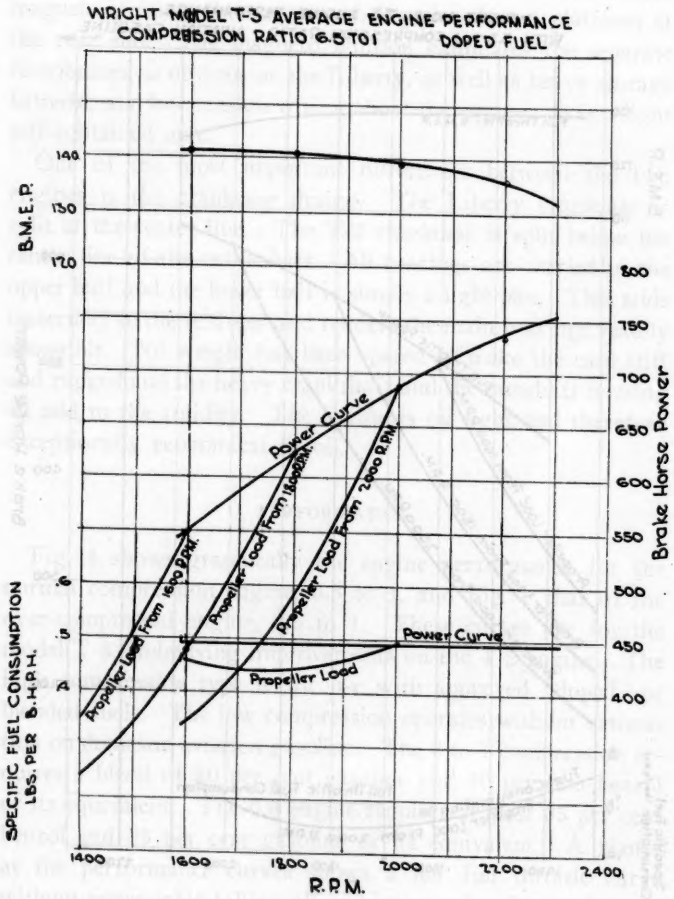

WRIGHT MODEL T-3 AVERAGE ENGINE PERFORMANCE
COMPRESSION RATIO 6.5 TO 1 DOPED FUEL
B.M.E.P.
140
130
120
SPECIFIC FUEL CONSUMPTION LBS. PER B.H.P.H.
.6
.5
.4
Brake Horse Power
800
750
700
650
600
550
500
450
400
Power Curve
Propeller Load From 1600 R.P.M.
Propeller Load From 1800 R.P.M.
Propeller Load From 2000 R.P.M.
Power Curve
Propeller Load
1400
1600
1800
2000
2200
2400
R.P.M.

FIG. 5.

with a propeller which will give 2000 R.P.M. at full throttle an engine with 6.5 to 1 compression can be depended on for 675 H.P. for taking off with a heavy load of fuel. Once the plane is in the air the engine can be throttled to, say, 1600 R.P.M. provided it can fly at 375 H.P. and at that propeller speed can have a specific fuel consumption of about .46 pound per B.H.P. per hour. We have, therefore, an engine capable of high power for take-off combined with good economy at reduced power at which reliability may be expected.

The full throttle curve is obtained on an electric dynamometer. From this curve the power to be used is selected and the propeller designed to give that power at full throttle in the plane. From the point chosen, the propeller load curve is dropped on the assumption that power absorbed decreases as the cube of the R.P.M. approximately. With a given propeller the power developed may be read from this propeller load curve. Fuel consumption full out is, of course, constant. Fuel consumption throttled gives the pounds per B.H.P. per hour and forms the basis of calculations for economical speed. There is a range of nearly 100 R.P.M. over which the specific fuel consumption is to all intents and purposes practically constant.

Figure 6 is the wind tunnel test data on which the plane design is based and the performance predicted. Fig. 7 gives the propeller characteristics of the propeller selected from which performance can be estimated. Fig 8 is the power curve showing the thrust horsepower for a range of air speed and for different loadings. It will be noted that the thrust horsepower required is a minimum for each loading condition at a certain small range of speed. For long range cruising the economical speed varies as the fuel is consumed. This is translated into terms of fuel in Fig. 9 and Fig. 10. Fig. 11 gives the cruising range for different gross weights and different fuel loading. From these can be determined what proportion of the useful load may be assigned to fuel and armament for a given range of operation. Fig. 12 gives the

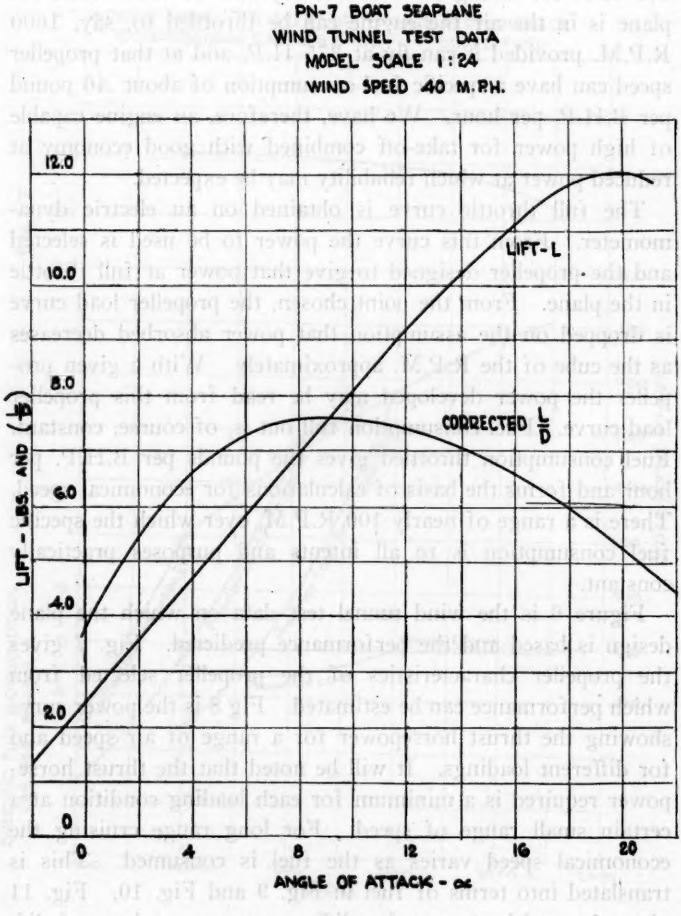

PN-7 BOAT SEAPLANE
WIND TUNNEL TEST DATA
MODEL SCALE 1:24
WIND SPEED 40 M.P.H.
LIFT - L
CORRECTED L/D
LIFT - LBS. AND (L/D)
ANGLE OF ATTACK - α
12.0
10.0
8.0
6.0
4.0
2.0
0
0
4
8
12
16
20

FIG. 6

PN-7 BOAT SEAPLANE
PROPELLER CHARACTERISTICS
(DURAND - NAVY SERIES)

P = 5.5' D = 10.5'

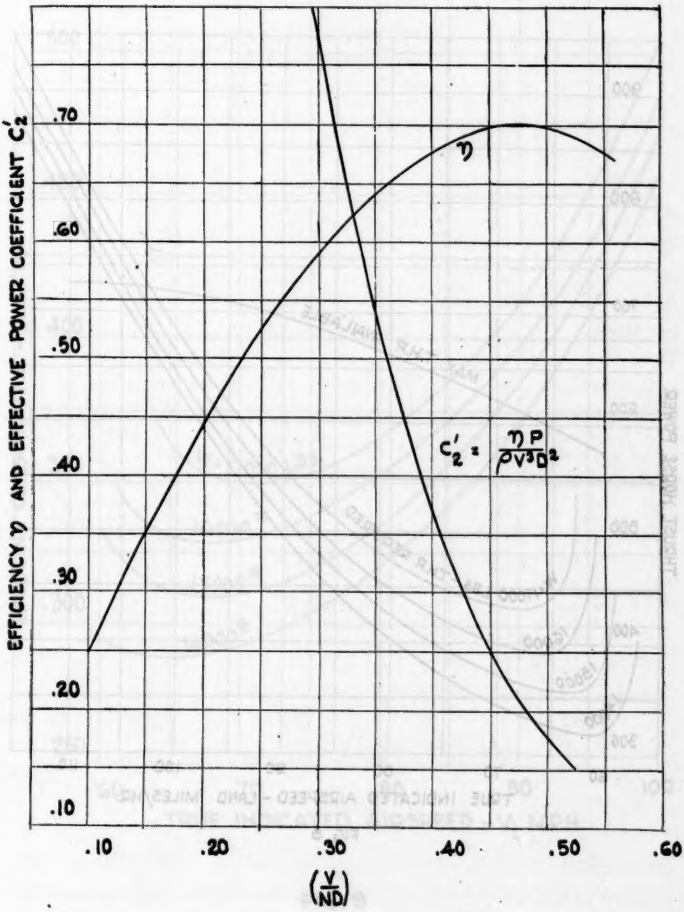


FIG. 7

PN-7 BOAT SEAPLANE
POWER CURVE

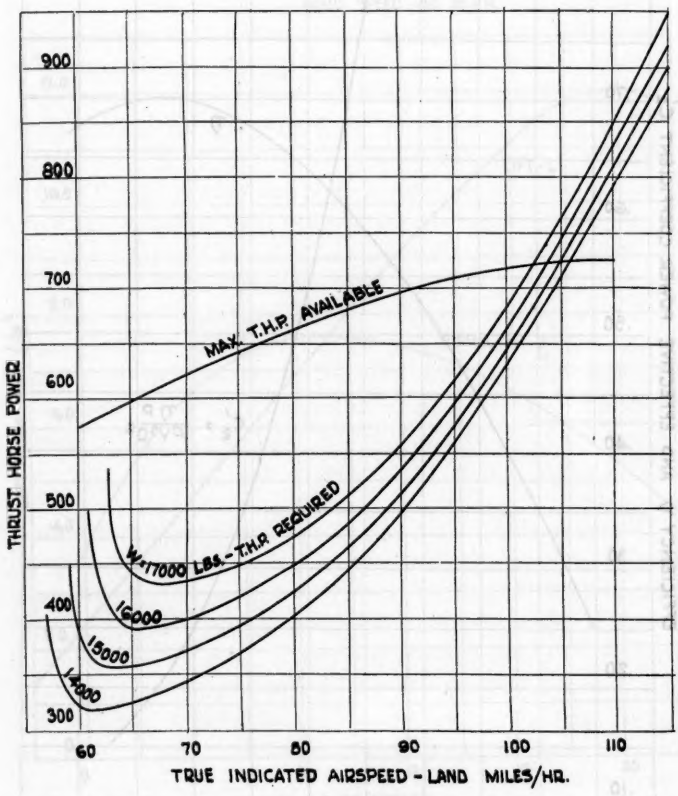


FIG. 6

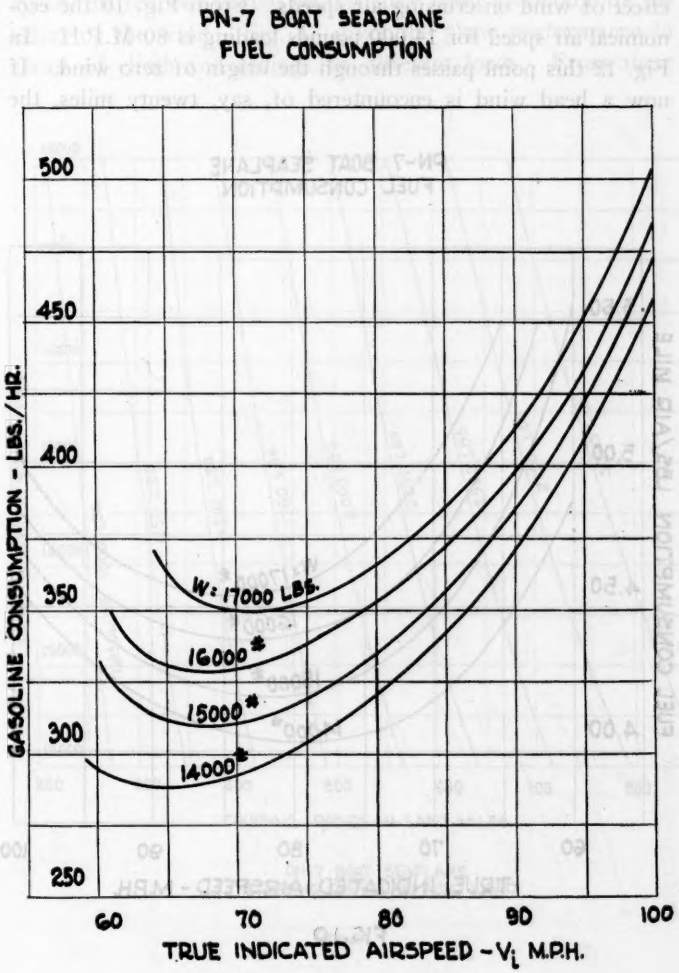

PN-7 BOAT SEAPLANE
FUEL CONSUMPTION
GASOLINE CONSUMPTION - LBS./HR.
500
450
400
350
300
250
W = 17000 LBS.
16000 #
15000 #
14000 #
60
70
80
90
100
TRUE INDICATED AIRSPEED - V_i M.P.H.

FIG. 9

effect of wind on cruising air speeds. From Fig. 10 the economical air speed for 14,000 pounds loading is 80 M.P.H. In Fig. 12 this point passes through the origin of zero wind. If now a head wind is encountered of, say, twenty miles, the

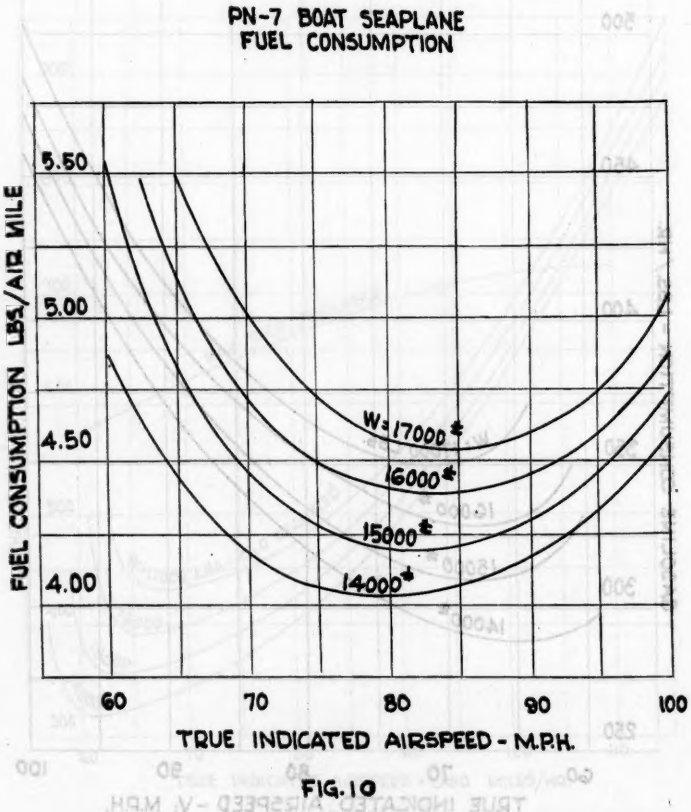


FIG. 10

economical speed is increased to 86 M.P.H. In other words, it pays to sacrifice some engine performance to reduce the time in the air and thus the effect of a head wind. Similarly for a fair wind of twenty knots it will pay to throttle to 76 miles air

speed, the reduced engine performance being overcome by the effect of the wind. Fig. 13 gives the plane performance in terms of climb and ceiling for different loads. From these

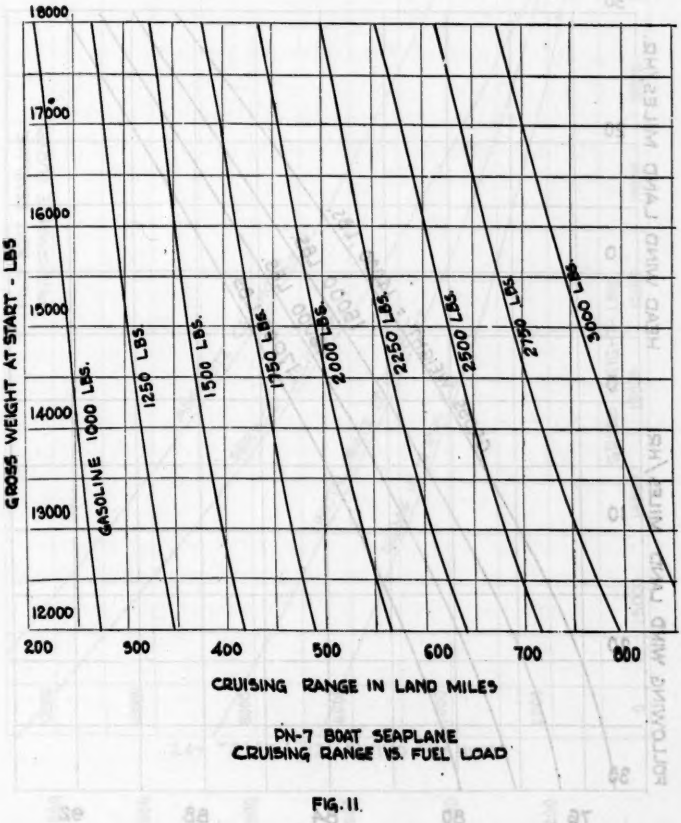


FIG. 11.

curves it is apparent how much more exactly performance can be measured and controlled in the air than on the surface of the sea.

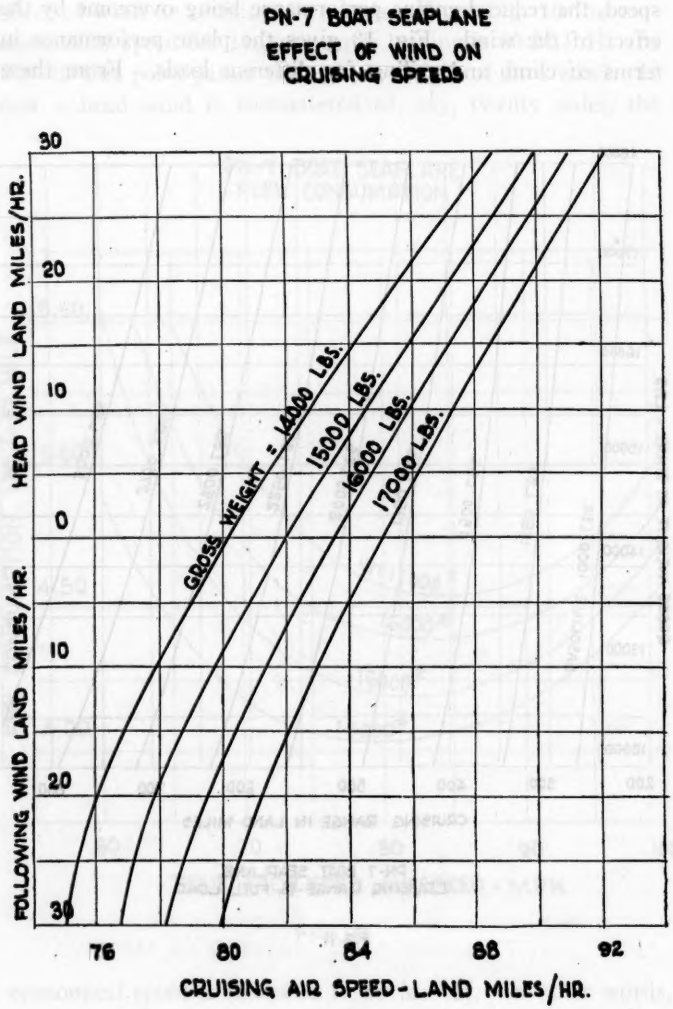

PN-7 BOAT SEAPLANE
EFFECT OF WIND ON
CRUISING SPEEDS
HEAD WIND LAND MILES/HR.
FOLLOWING WIND LAND MILES/HR.
30
20
10
0
10
20
30
GROSS WEIGHT = 14000 LBS.
15000 LBS.
16000 LBS.
17000 LBS.
76
80
84
88
92
CRUISING AIR SPEED - LAND MILES/HR.

FIG. 12

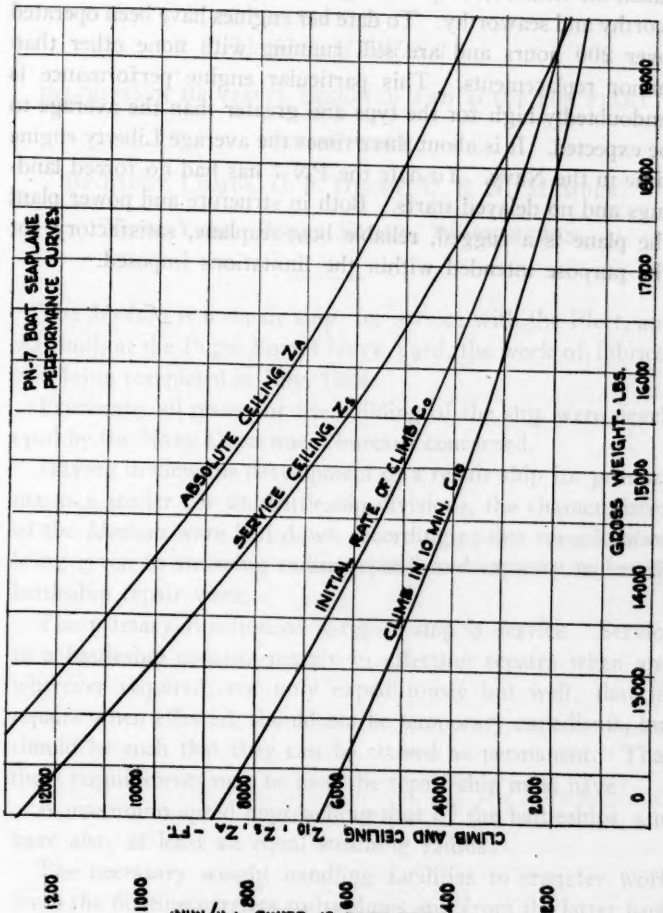

PN-7 BOAT SEAPLANE
PERFORMANCE CURVES
ABSOLUTE CEILING Z_A
SERVICE CEILING Z_s
INITIAL RATE OF CLIMB C_o
CLIMB IN 10 MIN. C_10
GROSS WEIGHT - LBS.
18000
17000
16000
15000
14000
13000
0
12000
10000
8000
6000
4000
2000
CLIMB AND CEILING Z_10 , Z_s , Z_A - FT.
1200
1000
800
600
400
200
INITIAL RATE OF CLIMB FT./MIN.

FIG:13

In service the PN-7 gave excellent performance. She has taken off with 16,500 pounds gross weight and has proved airworthy and seaworthy. To date her engines have been operated over 200 hours and are still running with none other than minor replacements. This particular engine performance is undoubtedly high for the type and greater than the average to be expected. It is about three times the average Liberty engine time in the Navy. To date the PN-7 has had no forced landings and no delayed starts. Both in structure and power plant the plane is a rugged, reliable boat-seaplane, satisfactory for the purpose intended within the limitations imposed.

U. S. S. *MEDUSA.*

DESCRIPTION OF VESSEL DESIGNED AND BUILT FOR FLEET REPAIR WORK.

By Lieut. Comdr. D. F. Ducey, U. S. N., Member.

Navy Yard, Puget Sound, Washington.

The *Medusa* is a repair ship, for service with the Fleet, and was built at the Puget Sound Navy Yard, the work of fabrication being completed in July, 1924.

Practically all plans for the building of the ship were developed by the Navy Department bureaus concerned.

Having in view the development of a repair ship for primary use as a tender for the battleship divisions, the characteristics of the *Medusa* were laid down accordingly; due consideration being given to steaming radius, speed, and capacity to handle battleship repair work.

The primary function of a repair ship is service. Service to a battleship consists mainly in effecting repairs when and wherever required, not only expeditiously but well; that is, repairs when effected, should not be temporary expedients, but should be such that they can be classed as permanent. That these requirements may be met, the repair ship must have:

A maximum speed approaching that of the battleships, and have also, at least an equal steaming radius;

The necessary weight handling facilities to transfer work from the floating carriers to its shops and from the latter back to the former, these must not only be of sufficient capacity to handle the probable maximum weights that may be encountered, but they must be of a permanent character to prevent exasperating and detrimental delays;

The proper tools, machines, appliances, manufacturing and testing facilities, and the personnel to undertake each and every job that may arise, and to handle it in a complete and thorough manner;

The necessary amount of storeroom space to carry not only its own supplies, but also a limited amount for issue;

Adequate accommodations for its own personnel, and in addition accommodations for a small excess of complement, especially insofar as officers are concerned;

Portable equipment, including boating facilities, for sending working parties to other vessels, for emergency work.

The *Medusa* fulfills all these requirements. The shops are spacious and their equipment is the last word in completeness and modernity. The extent of equipment compares most favorably with the average navy yard; and for certain classes of work, the equipment is not excelled by any navy yard.

HULL DATA.

Material	Medium Steel
Draft, designed, forward, feet and inches	19–4⅞
Draft, designed, aft, feet and inches	18–7⅛
Displacement at designed draft, tons	9,960
Displacement per inch at L. W. L., tons	53
Length between perpendiculars, feet and inches	460–00
Length overall, feet and inches	485–4⅞
Length at load water line, feet and inches	460–00
Beam, extreme, feet and inches	70–03¼
Beam, at load water line, feet and inches	70–03¼
Beam, molded, feet and inches	70–00
At designed draft, area immersed midship section, square feet.	1,274
At designed draft, area, load water line plane, square feet	22,400
At designed draft, wetted surface, square feet	35,250
Coefficient of fineness, block	.567
Coefficient of fineness, midship section	.954
Coefficient of fineness, load water line	.692

GENERAL DESCRIPTION—DECKS.

The *Medusa* is of the single screw type, with the machinery located aft and having three complete decks, main, second and third; a platform deck forward and aft; a forecastle deck; a

half deck between the second and third decks; an after upper deck; an after superstructure deck; a bridge deck; and a bridge.

The superstructure deck, extending between frames 89 and 148 has the boat stowage, vegetable stowage, disinfector, and lumber stowage, and four winches for hoisting boats and operating the booms on the main mast.

The bridge deck comprises the captain's quarters. One life boat is rigged on either wing.

The forecastle deck extends from the stem to frame 51, and provides space for the optical shop, anchor windlass, two 5-inch guns, one 3-inch gun and two deck winches for operating the booms on the foremast.

The upper deck extends between frames 90 and 148 (153 is the last frame). The space between frame 90 and 125 is utilized for shops, and abaft is the wardroom and wardroom officers' quarters.

The main deck has four main divisions: the space between the stem and frame 50 is occupied by the ship's offices, the repair officer's office and drafting room, C. P. O. living space, sick bay, supply office, clothing and small stores issuing room and paint mixing room. The space between frames 50 and 90 constitutes the primary handling space of the ship: here are located four large hatches; the two large derrick piers, having four booms each; the two small derrick piers, having one boom each; eight winches for handling the booms; and the gangways.

Between frames 90 and 120, the space is given over to the blacksmith and boiler shops.

Abaft of frame 120 are the warrant officer's living spaces, two 5-inch guns and the towing gear.

The second deck, forward of frame 36, is given up entirely to store rooms; between frames 36 and 74, there is the machine shop, electrical repair shop, and storerooms. Between frames 74 and 106 is the pattern shop, joiner shop and foundry. The remainder of the deck is crew's space. The steering engine room is well aft on this deck.

The half deck extends from the stem to frame 36. The lamproom, chain locker, gyro compass room, and storerooms are located on this deck.

From the stem to frame 36, the third deck is taken up with store rooms. The machine shop extends between frames 36 and 74, the foundry extends from frames 74 to 90. From frame 90 to 129 is taken up by the ice machine room, air compressor room, laundry, generator room, cold storage rooms, and store rooms. Abaft of frame 129 is crew space.

The platform deck is given over entirely to stores.

The hold has the forward and after magazine spaces, the fire and engine room compartments, fuel oil tanks and miscellaneous store rooms.

ANCHOR HANDLING.

There are three stockless type bower anchors, stowed in the hawse pipes and weighing 14,000 pounds, 14,075 pounds, and 13,905 pounds, respectively. Two are connected up for use; the other is a spare. In addition, there is provided one stockless stream anchor weighing 3000 pounds and one kedge anchor weighing 1645 pounds.

The anchor windlass is located on the forecastle deck between frames 10 and 13, and is of the horizontal spur geared type, with engines self contained on a single bed plate. There are two wildcats for handling the bower anchors and two gypsy heads on an intermediate shaft for working purposes and cargo handling.

The windlass engine is a 12 by 16 horizontal, duplex, and is capable of hoisting both anchors simultaneously.

STEERING

The steering engine was built at the Mare Island Navy Yard. The two cylinders are 10 inches in diameter by 10-inch stroke and designed for a working pressure of 125 pounds per square inch. The engine is fitted with a reversing valve and a follow-

up gear operated through a line of shafting, bevel gears and wire rope transmission from the pilot house and steering station on the upper navigating bridge. The valve may also be operated at the engine by means of a wheel on the end of the control shaft, which is also fitted with a rudder angle indicator for steering purposes.

The main steering gear consists of a forged steel shaft 6¼ inches in diameter with right and left hand 1½ lead double acme screw threads ¾ inch pitch. This shaft is fitted with cast steel nuts bushed for sliding on forged steel slide bars and having connections for the forward ends of the forged steel links, the after end of which connects directly to the cross head on the rudder stock.

In throwing the rudder from the midship position to 35 degrees hard over to one side requires 10.1 turns of the main screw shaft on the steering engine or 20.2 turns from hard over to hard over, and requiring 30 seconds of time.

LAUNDRY.

The laundry is similar to other service installations except in that the drainage goes to a large collecting tank in the fireroom, and from there is pumped overboard by means of two automatic electric rotary pumps.

The following equipment is installed:

1—42 inch by 54 inch washing machine, American Laundry Machine Co.
1—26 inch extractor, Tray Laundry Machine Co.
1—Set stationary tubs.
1—"Shaw" collar machine, Reed Manufacturing Co.
1—Dryer, American Laundry Machine Co.
1—16 inch by 48 inch ironer, Tray Laundry Machine Co.
1—Clothes presser, steam, Daly Manufacturing Co.
1—Starch mixer, steam, American Laundry Machine Co.
1—Hand ironing board.

GALLEY-SCULLERY AND BAKE SHOP.

The galley, bakery, butcher shop, and potato peeling rooms are located on the upper deck at frames 112 to 125, starboard side. The food service room, and general mess issuing room are located on the second deck, and a dumb waiter furnishes service between the galley and food service room.

COMMISSARY APPLIANCES.

No.	Appliance	Location	Manufacturer
1	5–3 ½ ft. Sec. Oil Range A.....	Galley	S. B. Sexton Stove and Manufacturing Co.
3	80–Gal Steam Kettles.....	Galley	Alum. Cooking Uten. Co.
1	60–Gal Steam Kettle.....	Galley	Alum. Cooking Uten. Co.
1	40–Gal Steam Kettle (Coffee).	Galley	Alum. Cooking Uten. Co.
1	Elec. Kitchen & Cake Machine	Galley	Read Machinery Co.
1	Elec. Meat & Food Grinder....	Galley	Enterprise Mfg. Co.
2	No. 2 Oil Bake Ovens.....	Bakery	V. Clad and Sons (1) Bramhall Dean Co. (1)
1	No. 1 Steam Proofer.....	Bakery	S. Blickman
1	Elec. Dough Mixing Machine.	Bakery	Century Machine Co.
1	Portable Metal Trough.....	Bakery	Navy Yard, Puget Sound
1	Elec. Dishwashing Machine....	G.M.Pantry	The Insinger Co.
1	Elec. Potato Peeling Machine.	P. P. Room	G. S. Blakeslee and Co.
1	Steam Warming Closet.....	Fd Ser.Rm.	Navy Yard, Puget Sound
1	Electric Toaster.....	Diet Ktch.	.....
1	8 inch Elec. Disc Stove.....	Diet Ktch.	.....

HEATING.

Heating of the various compartments is accomplished by radiators and a mechanical ventilating system. Radiators are installed in the officers' quarters aft, the forward living spaces, captain's cabin, pilot house, optical shop, and other small compartments. The mechanical, blast, system cares for the shops, sick bay and chief petty officers' quarters.

BLAST HEATERS.

Number.	*Location.*	*Capacity, cubic feet per minute.*
1	Upper deck, frame 121	5000
1	Second deck, frame 156	1000
1	Second deck, frame 112	5000
1	Second deck, frame 136	8000
2	Second deck, frame 56	8000
1	Third deck, frame 130	5000
1	Main deck, frame 14	2500
1	Main deck, frame 34	8000

The heater boxes are of the coil, manifold type; live steam is the heating agent. Each box has its own air supply. Humidification of the air is accomplished by the introduction of live steam, the amount of steam admitted being controlled by a humidostat. The humidifying steam valve is of the diaphragm control type, the compressed air for operating it being supplied by the humidifier compressor which is located in the air compressor room.

FUEL OIL FILLING AND SUCTION.

All fuel oil tanks are in the forward part of the ship.

In the fireroom, there is a four-valve manifold with connections to the fuel oil supply pump, the fuel oil service pumps, a cross connection to the bilge pumps, and an 8-inch loop that encircles all fuel oil tanks, this loop being well inboard.

The 8-inch loop serves for both suction and filling, the 6-inch suction lines from the individual tanks, instead of being led directly to the fireroom, as independent lines, tap into the loop, where there is a cut-out valve.

For filling, there are two 8-inch deck connections at frame 90, one on either side of the ship. These lines connect directly into the 8-inch loop, there being an overflow from the loop. The valves that connect the filling lines to the loop are interlocked with the valves on the overflow lines, this insuring that, while filling, the overflow lines are always open.

All tanks have a low suction, bottom of pipe being 3 inches from skin of ship; and in addition, four tanks, A-927-8-9-30F, have each a high suction, the bottom of the pipe being 15 inches from the skin of the ship.

Both the fuel oil supply and service pumps can serve the galley and the fuel oil tanks for the various shops. The supply pump has a 3½-inch overboard discharge, connecting into the fire and bilge pump discharge.

To discharge fuel oil to another ship, it would be necessary to use the 8-inch deck connections.

ELECTRICAL INSTALLATION.

The generating plant, consisting of four General Electric direct current machines, is located on the starboard side of the third deck, just over the engine room. There are two 300 K. W. and two 100 K. W. units; the latter located outboard of the former. The attendant auxiliaries, condenser, air pump, and circulating pump, are located almost directly below, in the engine room. All four units can be operated either condensing or non-condensing.

300 K. W. UNIT DATA.

Type: General Electric, D. C.; interpole, horizontal, indirect connected, turbo driven.

Voltage	125
R. P. M.; generator	750
Winding	compound
Number of poles	8
Sets of brushes	8
Lubrication	self-contained oil pump
Turbine	Curtis 3 stage
Steam pressure, pounds per square inch	160 to 200
Horsepower	460
Reduction gearing	Poole Engineering and Machine Co.
Reduction ratio	3967 to 750

100 K. W. GENERATOR DATA.

Type; General Electric, D. C.; interpole, horizontal, indirect connected, turbo driven.

Voltage	125
R. P. M.; generator	750
Winding	compound
Number of poles	8
Sets of brushes	8
Lubrication	self-contained oil pump
Turbine	Curtis 3 stage
Steam pressure, pounds per square inch	160–200
Horsepower	155
Reduction gearing	Poole Engineering and Machine Co.
Reduction ratio	3600 to 1200

SWITCH BOARD.

The main switch board is located just forward and adjacent to the generators, extending between frames 106 and 110; and is used for supplying the power and lighting panels that are located in the various parts of the vessel.

There are panels as follows:

1 for interior communication systems;
3 for power distribution;
2 for the generators;
2 for the lighting system and searchlights.

The panels used for the generators are fitted with the usual voltmeters, ammeters, watt-meters, main and equalizer switches.

The panels used for the lighting system and searchlights are fitted with the usual voltmeters, ammeters, and switches used for making tests and checking the meters on the generator's panels.

Panel No.	Supplies.
1	All 20 and 125 volt I. C. systems; two interior communication generators; switches for ship's service telephones; loud speaking telephones; Gyro compass equipment.

2 Power panels, numbers, 6, 8, 10, 13, 17, 19, 20, and 23; Interior communication panel; Radio and battery charging panel.

3 Power panels, numbers, 1, 2, 4, 5, 7, 9, and 12; Core drying oven.

4 Power panels, numbers, 3, 11, 14, 15, 16, 18, 21, and 22; Core baking oven.

5 Panel for two 300 K. W. generators.

6 Panel for two 100 K. W. generators.

7 Lighting distribution panels, numbers, 1 and 5, on battle circuits; General lighting panels, numbers, 1, 2, 3, 4, 5, and 6; Two 24-inch high-power searchlights.

8 Battle circuit lighting distribution panels, numbers, 2, 3, 6, and 7; General lighting panels, numbers, 7 and 8; Two circuits for engine, evaporator and fire room; One 12-inch signal searchlight.

LIGHTING.

From the main switchboard, lighting is distributed throughout the ship, through seven circuits and eight lighting distribution panels.

The seven lighting circuits feed the following: Two 24-inch searchlights, two 12-inch signal searchlights, outlets, engine room, fire room, and evaporator room.

LIGHTING DISTRIBUTION PANELS.

No.	*Location.*	*Supplies.*
1	Bridge deck, amidships, frames 47–48.	All navigation, signal, and anchor lights; captain's quarters, bridge, pilot house, chart house, and optical shop.
2	Superstructure deck, amidships, frames 120–121	All lighting for wardroom and warrant officer's quarters; galley, bakery, butcher shop, crew space, crew's reading room, radio room, and all outside lights on superstructure and upper deck between frames 90 and 136.
3	Main deck, stbd., frame 32–33.	All lighting on main, second, third, platform and hold decks to frame 50.

No.	*Location.*	*Supplies.*
4	Blacksmith shop, main deck, port, frame 96.	All lighting on main deck between frames 50 and 90, and all lighting on upper deck between frames 90 and 120.
5	Second deck, amidships, frame 74.	All lighting on second deck between frames 50 and 24.
6	Second deck, frames 95–96.	All lighting on second, third, platform and hold decks between frames 74 and 106, except fireroom space.
7	Second deck, frames 123–124.	All lighting on second, third, platform and hold decks between frame 106 and stern.
8	Third deck, frame 74.	All lighting on third and hold decks between frames 36 and 74.

AUXILIARY LIGHTING.

The auxiliary lighting system consists of two separate 140 ampère hour batteries. Each set has 5 trays of 3 cells each.

Set number one furnishes lighting, through relays, to the battery room, sick bay, isolation ward, and operating room.

Set number two furnishes lighting, through relays, to the fire room, dynamo room, engine room, evaporator room, and radio room.

SEARCHLIGHTS.

There are two General Electric Co. high power, 24-inch, searchlights; both are mounted on towers, the forward tower on the bridge decks between frames 48 and 50, and the after tower on the upper deck, between frames 132 and 134.

SIGNALS.

For visual signaling, there is the following equipment:

1—12-inch signal searchlight outlet on each wing of bridge.
2—truck lights; one on foremast, and one on mainmast.
2—blinker lights; port and starboard yard arms of foremast.
Man-overboard and break-down lights on mainmast.
Screened speed light on after searchlight platform.

POWER.

From the main switch board, power is distributed throughout the ship through 26 power circuits, which feed the following:

Battery charging panel.
Interior communication switchboard.
Core baking oven.
Core drying oven.
Radio room.
Shore line communication room.
Twenty-three power distribution panels.

POWER DISTRIBUTION PANELS.

No.	*Location.*	*Supplies.*
1	Machine shop, forward, starboard, third deck, frame 36.	Hydraulic beam forging press; lathe, turret, vertical, 36-inch; cold saw, metal; boring mill, vertical, 73-inch; lathe, turret, vertical, 24-inch; boring mill, vertical, 42-inch; radial drill; bench grinder; receptacle (for portable cylinder boring machine).
2	Machine shop, forward, port, third deck, frame 36.	Hack saw; planer 30 inches by 30 inches by 6 feet; 10-inch crank slotter; 2 24-inch shapers; 3 milling machines, universal; 36 inches by 24 inches by 8 feet planer; 28-inch upright drill press; ventilating motor No. 8.
3	Machine shop, aft, starboard, third deck, frame 74.	Bench drill, sensitive; 28-inch upright drill press; 2—14 inches by 8 feet engine lathes; 2—16 inches by 12 feet engine lathes; 2—18 inches by 12 feet engine lathes; 48 inches by 72 inches by 15 feet gap extension lathe; 14 inches by 1½ inches wet and dry grinder; boring, drilling and milling machine (high bed); one-ton electric hoist.
4	Machine shop, aft, port, third deck, frame 74.	2—14 inches by 8 feet engine lathes; 2—16 inches by 12 feet engine lathes; 2—24 inches by 14 feet engine lathes; 28 inches by 48 inches by 14 feet gap extension lathe; bench drill, sensitive; boring, drilling and milling machine (low bed); 16 inches by 2 inches wet grinder; three-ton traveling crane; one-ton electric hoist; receptacle (for portable cylinder boring machine).

No.	*Location.*	*Supplies.*
5	Foundry, aft, port, third deck, frame 90.	Ventilating sets, Nos. 27 and 28; tumbler, double bench grinder; smelting blower; band saw; magnetic separator; three-ton traveling crane; one-ton electric hoist.
6	Laundry, aft, starboard, third deck, frame 106.	Collar shaper; flat work ironer; tumbler drier; extractor; washer; ventilating set No. 31.
7	Dynamo room, starboard, platform deck, frame 110.	Ventilating sets Nos. 32, 33 and 34; Oil separator; exhauster fan.
8	Machine shop, forward, second deck, port, frame 36.	12 inches by 6 feet tool lathe; 2 8½ inches by 22 inches precision lathes; universal cutter reamer and grinder; 10 inches by 36 inches universal grinding machine; bench drill, sensitive; double bench buffing machine; 2 universal milling machines; ½-inch by 6-inch centering machine; 2 16-inch shapers; wet and dry grinding machine.
9	Electric shop, starboard, second deck, frame 69.	Tapering machine; 18-inch upright drill press; 16 inches by 10 feet engine lathe; 24 inches by 14 feet engine lathe; armature coil winding lathe; 2 electric bake ovens, one large and one small; bench drill; 8½ inches by 22 inches precision lathe; coil winding machine; bench grinder.
10	Machine shop, aft, port, second deck, frame 74.	Gear cutter; bench drill; universal milling machine; 22½-inch upright drill dress; bench grinder; 2¼ inches by 26 inches turret lathe; ⅝ inches by 4½ inches turret lathe; 6—14 inches by 8 feet engine lathes; plug-in receptacle (for portable tools).
11	Machine shop, aft, starboard, second deck, frame 74.	Ventilating motor Nos. 16, 17, 18, 19, and 20; moving picture machine outlet.
12	Pattern shop, amidships, port, second deck, frame 95.	38-inch band saw; patternmakers' gap lathe; mortiser and borer; 24-inch jointer; 30-inch sander; patternmakers' lathe; oil stone grinder; 26-inch universal saw table; double spindle shaper; 2—8-inch jointers; 26-inch surfacer; 2 bench grinders; hot-water circulating pump.
13	Pattern shop, amidships, starboard, second deck, frame 95.	Ventilating sets 21, 22, 29, 29A, and 30.
14	Crew space, starboard, second deck, frame 122.	Power panel No. 15; ventilating sets Nos. 23, 36, and 38; print shop; whip hoist.

No.	*Location.*	*Supplies.*
15	Steering eng. room, starboard, second deck, frame 147.	Ventilating sets Nos. 24, 25, and 26.
16	Main deck, amidships, starboard, frame 30.	Ventilating sets Nos. 11, 12, 13 and 14; whip hoist; sterilizer in sick bay.
17	Blacksmith shop, main deck, starboard, frame 120.	Blower; cold saw; 4-foot radial drill; universal plate machine; 2 bench grinders; 30-inch throat punch; wet grinder; roll bending machine; upright drill press; 30-inch throat shear; one-ton crane hoist; two monorail hoists.
18	Blacksmith shop, main deck, starboard, frame 120.	One fixed welder with two welding panels; two portable welders.
19	Optical shop, forecastle deck, amidships, frame 45.	Cabinet lathe; double bench grinder; three sensitive drill presses; 10-inch lathe; 12-inch lathe; two milling machines; periscope pump; optical grinder; watchmaker lathe; electric oven; electric still; electric dental motor.
20	Pipe, tinsmith and plating shop, upper deck, port, frame 105.	Pipe threading machine; hydraulic bender; power shear; pipe expanding and flanging machine; buffing machine; bench grinder; 16 inches by 8 feet engine lathe; ventilating sets 1A and 1B; wet and dry grinder; bench buffing machine; 22½-inch upright drill press; plating shop motor generating panel.
21	Upper deck, amidship, frame 109.	Ventilating sets Nos. 1, 2, 3, 4, 5, 6, 7, and 39; two electric heater, radio room; power panel No. 22.
22	Upper deck, amidships, frame 120, starboard.	Meat grinder; potato peeler; cake mixing machine; dough mixer; dish washer.
23	Evaporating room, port side of hold, frame 126.	Four fresh water pumps; two brine overboard pumps; two condensate pumps; two brine circulating pumps; two distilling condenser circulating pumps.

ELECTRICAL SHORE LINE CONNECTIONS.

There is one shore line connection box, capacity 3000 ampères, that can be used either for receiving power or supplying power to other vessels.

BATTERY CHARGING.

The battery charging equipment consists of one Corey battery charging panel which can be used for charging the auxiliary lighting, telephone, and gun firing batteries. This equipment can also be used for main repair work on small batteries.

ALARM SYSTEM.

The fire alarm annunciator, having 48 drops, is located on the bridge deck. There are installed 62 thermostats; all magazine thermostats function at 105 degrees, Fahrenheit, and those in the store rooms at 150 degrees.

POWER MOTORS.

One hundred and fifty-four motors, installed in various parts of the ship, are used in operating equipment in the following compartments: Laundry, print shop, galley, bake oven, foundry, pattern shop, optical shop, machine shop, electrical shop, and evaporator room.

VENTILATION MOTORS.

Thirty-nine motors, varying in size from ¼ horsepower to 7 horsepower, are used for the supply and exhaust ventilating fans. Nine motors are used for the fans employed in connection with the blast heaters.

ELECTRIC HEATERS.

Outlets for electric heaters are provided in the pilot house, bridge, and radio room. Six portable heaters, two of 1,000 watt capacity, two of 500 watt capacity, and two, non-magnetic, of 500 watt capacity, are furnished.

I. C. SYSTEM.

The I. C. switchboard, energized from panel number two of the main switchboard, is located on the port side of the dynamo room, between frames 106 and 110. The 20-volt

bus bars of the I. C. switchboard are fed by two motor-generators, and supply all call bell, fire alarm, and pneumercator systems.

CIRCUITS.

Designation.	*Service.*
A.	Captain's, wardroom, and warrant officer's quarters.
B.R.	Life buoy releases.
D.A.	Docking telegraph.
E.	All voice tubes, except fire control.
F.	Fire alarm system.
G.	General alarm gong system.
H.	Boat hour gongs.
J.	Ship service telephones.
K.	Shaft revolution indicator system.
L.	Steering telegraph system.
L.C.	Gyro compass system.
M.B.	Engine order telegraph.
M.C.	Loud speaking telephones.
N.	Rudder indicator system.
Q.A.	Air lock indicator system.
V.A.	Secondary battery salvo signal.
X.	Pneumercator system.

RADIO INSTALLATION.

The Radio Installation consists of one 2 K. W. Arc Transmitter, one 2 K. W. Spark Transmitter, one Motor Buzzer as auxiliary equipment for the Spark Transmitter for low-powered signalling, one Radio Telephone Transmitter and Receiver, one Long Wave Receiver, one Medium Wave Receiver, and a Radio Compass.

RADIO ROOM.

The radio room is located between frames 112 and 118 on the upper deck, port side, aft, and has a deck space of slightly more than 800 square feet. This large space allowed of installing the equipment therein to the best advantage as to operation, inspection and upkeep.

The forward and after bulkheads are sound-proofed; no such provision was required for the inner and outboard bulkheads, the former being adjacent to a passageway and the outer bulkhead being the outer hull of the ship.

Lighting is provided for by four 100-watt units fitted with reflectors, fed from the ship's electric plant; four 30-volt, 25-watt, auxiliary lighting units are installed, fed from storage batteries; this auxiliary lighting becoming effective automatically upon failure of the main lighting circuit; additional illumination is provided, during daylight hours, via three large airports fitted with translucent glass discs.

Ventilation is amply provided for via the above air ports, two 6-inch air supply ducts connected to a ventilating blower, and by a large natural exhaust air duct having a very short direct connection to the open deck above the Radio Room.

Heating is accomplished by two electric heaters.

Interior communication is provided for by a Ship's Service Inter-Communicating Telephone and one large voice tube connecting by branches to the Bridge, Pilot House, and the Radio Compass Room.

RADIO EQUIPMENT.

One 2 K. W. Arc Transmitter with the necessary motor-generator, which is installed on the dynamo flat, just aft of the main switchboard.

One 2 K. W. Spark Transmitter, with the necessary motor-generator, which is installed on the dynamo flat, just aft of the main switchboard.

A Motor Buzzer, with the storage batteries furnished therewith, which are installed in the radio battery room.

A Radio Telephone Transmitter and Receiver, the storage batteries furnished for operation of the dynamotors, which batteries are installed in the radio battery room.

One Long Wave Receiver, complete with filament and plate storage batteries. The battery charging arrangement for these batteries is installed in the radio workshop.

One Medium Wave Receiver, complete with filament and plate storage batteries. The charging arrangements for these batteries are installed in the radio workshop.

The radio battery room is located between the radio room and the radio workshop, between frames 116½ and 118, and has an area of about sixty square feet. This space is painted with an acid-resisting compound for preservation, is fitted with shelves, and accommodates the storage batteries for operation of the Motor Buzzer and the Dynamotors of the Radio Telephone Equipment. Wiring is installed to allow of charging these batteries from charging panels installed in the radio workshop.

The radio workshop is located between frames 118 and 122, just abaft the radio room and radio battery room, and has an area of about 350 square feet. Two large work benches are provided, being fitted with drawers and lockers under same; three large metal lockers are provided for storage of instruments, spare parts, etc. Battery charging panels are mounted on the inboard bulkhead, functioning for the Radio Telephone Dynamotor batteries, the Motor Buzzer batteries and the plate and filament batteries.

The radio power supply circuit is fed from the power panel of the main distribution switchboard.

The radio compass room is located on the bridge deck, just abaft the emergency cabin, between frames 44 and 47. A 1000-gallon fresh water gravity tank cuts off about four feet of this space, fore and aft, but a clear area of about 100 square feet is left for compass equipment. This compartment is sound-proofed by means of a 1-inch cork lining. A type "A" Compass Coil House is installed directly over this space, the house consisting of a hexagonal wood frame, fitted with a solid top and having eight removable wood panels. The whole is enclosed with a canvas cover, so arranged as to be removable.

The special loop antenna utilized for receiving radio compass signals is installed in the Compass Coil House, its position in azimuth being controlled by a hand wheel in the Radio Com-

pass Room via a control shaft. In addition to the regular Radio Compass Receiver, a Sperry Gyro Repeater Compass installed in the Compass Room, allows of converting relative compass bearing to true bearings.

ANTENNAE.

In addition to the Radio Compass Loop Antenna, the following antennae are provided:

MAIN ANTENNA.

Two similar antennae of the cage type, 3 feet diameter, 250 feet long, are suspended between the fore and mainmasts, 166 feet above the waterline, parallel to each other at a distance of 21 feet, with the after ends of the two antennae connected together and joined to a 6-inch cage rat-tail; the rat-tail connecting to the radio room equipment through the usual entering insulator. This antenna is used for Spark or Arc Transmission and safe-guards are provided to prevent energizing it whenever the Radio Telephone Antenna is connected to the Radio Telephone equipment. All receiving, other than radio telephone receiving, is via the main antenna.

RADIO TELEPHONE ANTENNA.

This is a single 6-inch cage antenna suspended from the fore and aft stay between the fore and main tops. The antenna leads down and aft to a point on the forward side of the mainmast, at the level of the top of the smoke pipe, connecting from that point to the radio room, entering the insulator located there by means of a stranded phosphor bronze cable rat-tail.

There is one 2 K. W. Spark Transmitter. Nine wave lengths, with a range from 300 to 1805 meters, are provided for. The wave changer is marked in Kilo-cycles. A break-key system is not fitted. Both hand and automatic starting of the motor generator are provided for.

The Motor-Buzzer is not fitted as a complete motor-buzzer in itself, but is fitted for use in conjunction with the 2 K. W. quenched-spark transmitter when low power signalling is desired.

The 2 K. W. Arc Radio Transmitter, normal arc voltage 350, manufactured by the Federal Telegraph Company, is arranged for continuous wave transmission, utilizing the back shunt signalling system. In addition, it is equipped with a chopper device for interrupted continuous transmission. The range of wave lengths is 300 to 2400 meters, arranged in nine steps. The chopper is used on waves below 315 Kilo-cycles. This set is operated as on undamped wave transmitter.

The Long Wave Receiver is fitted with a separate control box and with a two-step audio-frequency amplifier; the amplifier is common to both the long and medium wave receivers, a 3-pole transfer switch being used in changing from one to the other. For filament lighting, a 6-volt, 75 A.H. Edison storage battery is provided. A 60-volt, 2½ A. H. storage battery is provided for the plate circuit. A battery charger is installed in the radio workshop for charging these batteries in place. This set is adopted for all around work.

The Medium Wave Receiver, self-contained detector and control, of a transfer switch, utilizes the two-step audio-amplifier used with the long wave receiver. This set is similar to the long wave receiver and is provided with filament and plate storage batteries, and battery charging arrangements.

The Radio Telephone, 5-watt, wave length range 256 to 600 meters, consists of the following units:

Dynamotor system; Switchboard; Transmitter-Receiver; Amplifier; Head set (2); Hand set; Extension box; Loud speaking phone; Transmitter; Push button.

For remote control of the transmitter-receiver, the extension box, loud speaker, push button, one of the head sets and the transmitter, are installed in the emergency cabin. For operation of the dynamotors, there is provided in the radio battery room, two 32-volt, 40 A. H., lead-acid storage batteries. This

battery equipment, in duplicate, permits of always having one set of batteries undergoing charging.

A Radio Compass, fitted with coil system, and coil house, has the following receiving equipment:

Tuning unit; Compensating condenser; Compensating loading condenser; Radio frequency driver; Amplifier; Telephone jack box; Plate battery, dry; Filament battery, single lead-acid cell, 2-volt, 80 A. H.

BATTERY.

The armament consists of four 5-inch 51-caliber rapid-fire guns and two 3-inch 50-caliber anti-aircraft guns. The 5-inch are mounted, one on each side of the forecastle deck, well forward, and one on each side of the main deck, well aft. Both the anti-aircraft guns are mounted amidships; number one is on a raised platform on the forecastle deck, and number two is on the after end of the superstructure deck, just abaft the searchlight tower.

All guns are served from magazines located in the hold deck and directly in the vicinity of the guns. For handling the ammunition there are two electric whip hoists, one forward and one aft, operated by Westinghouse motors. One 5-inch loading machine and two range finders complete the battery installation.

MACHINERY LAYOUT.

GENERAL.

The machinery layout consists of two express type boilers, located abreast each other, in a single compartment extending between frames 97 and 106; and two turbines, one high pressure and one low pressure, arranged on either side of the center line, and driving the propeller shafting through double reduction gearing. The main propelling units and their attendant auxiliaries are in one large compartment located between frames 106 and 120. While the dynamos' auxiliaries are

in the engine room, the dynamos, as well as the ice machines, evaporators, etc., are located outside the engine room space. The estimated shaft horsepower is 7,000; the corresponding speed is 17½ knots.

BOILERS.

There are two Bureau of Engineering, express type, oil-burning boilers, similar to those installed in the direct drive destroyers of the 119 to 124 group.

BOILER DATA.

Number of boilers	2
Designed working pressure, pounds per square inch	215
Steam drums, per boiler	1
Diameter of steam drums, inches	48
Water drums, per boiler	2
Diameter of water drums, inches	24
Length of steam drums, feet and inches	13–5 15/16
Length of water drums, feet and inches	12–6
Thickness of steam drums, inch	19/32
Thickness of steam drums, tube sheets, inches	1 29/64
Thickness of water drums, inch	17/32
Thickness of water drums, tube sheets, inch	7/8
Number and size of manholes in steam drum, inches	1–11 by 15
Number and size of manholes in each water drum, inches	2–11 by 15
Number rows generating tubes (2 groups)	4
Number generating tubes, per boiler	174
Number rows circulating tubes (2 groups)	34
Number circulating tubes, per boiler	2,482
Outside diameter generating tubes, inches	1⅝
Outside diameter circulating tubes, inches	1⅛
Thickness generating tubes, inch	.134
Furnace volume, per boiler, cubic feet	578.9
Heating surface, per boiler, square feet	7,000
Safety valves	manufactured by Star-Brass Mfg. Co.
Six safety valves, duplex, inches	4½
Number registers per boiler	7
Type register	Bureau Eng. Natural Forced Draft
Atomizers	Bureau Eng. Standard
Number smoke pipes	1
Diameter smoke pipe, feet	7
Height smoke pipe above furnace floor, feet, inches	90–6

The boilers are bricked and insulated in accordance with the General Specifications for Machinery.

MAIN PROPELLING UNITS.

REDUCTION GEAR DATA.

	Wheel	*H. P. Pinion*	*L. P. Pinion*
Number of teeth	66.5	43	43
Pitch, circle, diameter	144.295	9.33	9.33
Diameter over teeth	144.666	9.701	9.701
R. P. M.	110	1700	1700
Circular pitch	.681677		
Spiral angle	31 degrees, 21 minutes, 47.3 seconds.		

The gear spider is cast iron and has eight webs. The rim is forged steel. The spider is secured to the shaft by a taper fit with keys and a lock nut. The thrust collar is integral with the shaft.

There are 24 oil spray nozzles in the gear case; being on both the top and bottom of low pressure pinion, and on the top side only, of the high pressure pinion.

TURBINES.

For going ahead there is one high pressure and one low pressure turbine; connected through flexible couplings, each to a pinion. These turbines are of the reaction-drum type.

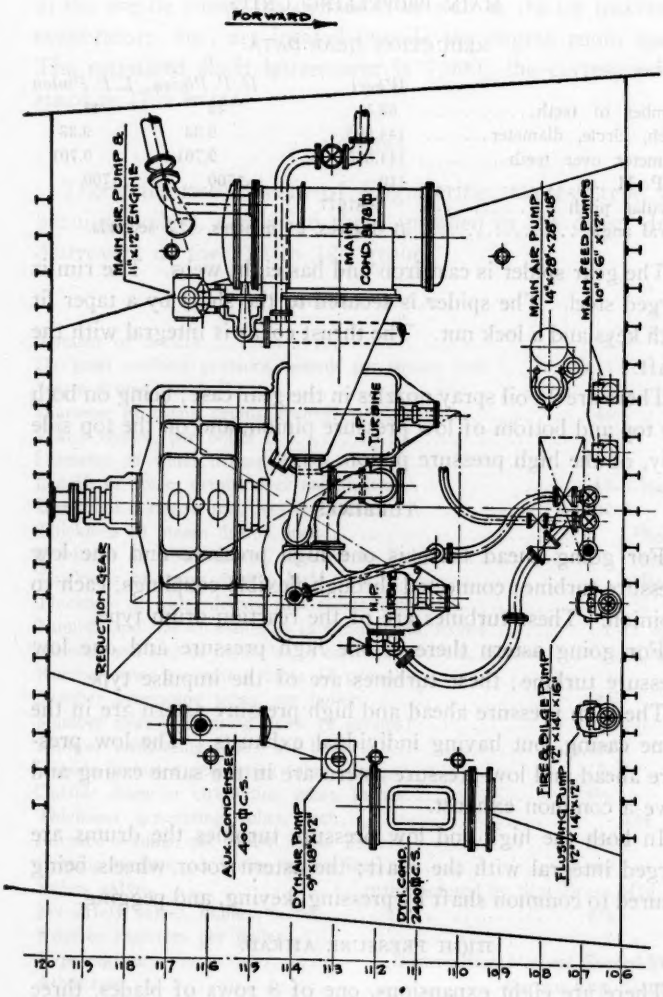
For going astern there is one high pressure and one low pressure turbine; these turbines are of the impulse type.

The high pressure ahead and high pressure astern are in the same casing, but having individual exhausts. The low pressure ahead and low pressure astern are in the same casing and have a common exhaust.

In both the high and low pressure turbines the drums are forged integral with the shaft; the astern rotor wheels being secured to common shaft by pressing, keying, and pegging.

HIGH PRESSURE AHEAD.

There are eight expansions, one of 8 rows of blades, three of 8 rows of blades, and four of 4 rows. For low powers, steam is admitted to the first expansion; for higher powers, the first expansion of 8 blades, is by-passed.



U. S. S. "MEDUSA". ENGINE ROOM LAYOUT.

The blading is of the usual reaction section, machined from stock. The blade root, for securing, is serrated. All blades are thinned at the tips. The binding strips, one to each row of blades, instead of being interlaced, are soldered to the blade directly, there being a slot, for the wire, milled in steam inlet edge of the blade.

The casing is of high grade cast iron. The bearing housing is cast integral with the turbine casing.

HIGH PRESSURE ASTERN.

The high pressure astern has one wheel carrying three rows of impulse blading. All blades are machined from stock. All moving blading has shrouding; the shroud bands, 20¾ inches long, are put on in halves and then soldered to the blades.

Steam is admitted through 48 nozzles, covering an arc of 157 degrees.

LOW PRESSURE AHEAD.

In the low pressure, there is a drum, forged integral with the shaft, carrying three expansions of 4 rows each; and four wheels, having a pressed fit, keyed and pegged to the shaft, carrying 8 rows of blades. The blading in this turbine is the same as in the high pressure. The fixed blading has a dovetail root section.

LOW PRESSURE ASTERN.

The low pressure astern has one wheel, secured the same as the high pressure astern wheel, carrying 3 rows of blades of the impulse type. These blades are secured as in the high pressure, except that in the third row, the four blades on either side of each expansion opening in the shrouding, are secured, all eight, together by a reinforcing wire.

Steam is admitted through 72 nozzles, 36 in the top nozzle block and 36 in bottom nozzle block; the arc of admission is 314 degrees.

MISCELLANEOUS FEATURES.

All blading is machined from stock.

All rotor wheels have a press fit, are keyed, and pegged.

A micrometer is fitted on the high pressure ahead turbine.

Finger pieces are provided for the low pressure turbine.

The thrust block pedestals are cast integral with the turbines.

A monel metal ring is secured to the steam end of the high pressure turbine drum; this provides a non-corrosive bearing surface for taking micrometer readings.

All moving blades have a serrated root section.

All fixed blades have a dove-tail root section.

The impulse blading is shrouded.

The reaction blading has reinforcing wire.

TURBINE DRAINAGE.

Owing to the turbines being well above the main air pump suction, the drainage is simple. The high pressure turbine drains to a well in the low pressure turbine, this well having a line, with a check valve, leading to the air pump suction.

VACUUM SYSTEM—MAIN AND AUXILIARY.

One main condenser, located on the port side of the engine room, and abreast of the low pressure turbine, handles the main exhaust and also the dynamo and auxiliary exhaust, when necessary.

DATA.

Type	double pass, surface
Tube packing	rolled inlet ends, ferruled outlet ends
Cooling surface, square feet	8178
Diameter of tubes, outside, inch	⅝
Thickness of tubes, mils	49
Number of tubes, each	3999
Length between tube sheets, inside, feet and inches	12–6
Thickness of tube sheets, inches	1⅛
Diameter of shell, outside, feet and inches	6–8¾

There is one independent air pump for the main condenser, of vertical, single-acting, twin-beam type, with two steam cylinders. This pump, through the wet suction pipe which leads to a water seal, takes the condensate from the main condenser. The turbine drain line from the low pressure turbine drain well taps in between the water seal and main air pump. There is a check valve in the drain line.

The dry suction pipe from the main condenser leads to an augmenter condenser, with an ejector installed between the augmenter condenser and the main condenser, and then from the augmenter to the main air pump suction (wet), at a point between the water seal and the air pump.

DATA.

Type	uniflow, surface
Tube packing	expanded at inlet end, ferruled at outlet end
Cooling surface, square feet	110
Diameter of tubes, outside, inch	⅝
Thickness of tubes, mils	49
Number of tubes	206
Length between tube sheets, inside, feet and inches	3–3
Thickness of tube sheets, inch	1
Diameter of shell, feet and inches, outside	1–7
Diameter ejector nozzle, inch	5/16
Steam pressure, pounds per square inch	215

The auxiliary condenser, served by a combined horizontal air and circulating pump is located well above the floor plates on the starboard side of the engine room, just outboard the main gear casing. This condenser has connections for handling the auxiliary exhaust.

DATA.

Type	double pass, surface
Tube packing	ferruled both ends
Cooling surface, square feet	400
Diameter of tubes, outside, inch	⅝
Thickness of tubes, mils	49
Length between tube sheets, inside, feet and inches	5–8¼
Thickness of tube sheets, inch	⅞
Diameter of shell, outside, feet and inches	2–0¼

DYNAMO CONDENSER.

The dynamo condenser is located on the port side of the engine room, almost directly below the dynamos, which are located on the deck above. The exhaust piping arrangement is such that this condenser can also be utilized to handle the auxiliary exhaust.

DATA.

Type	double pass, surface
Tube packing	rolled at inlet ends, ferruled at outlet ends
Cooling surface; square feet	2400
Thickness of tubes, mils	49
Number of tubes	2096
Length between tube sheets, inside, feet and inches	7–00
Thickness of tube sheets, inch	1
Diameter of shell, outside, feet and inches	5–0¾

This condenser has an independent air and an independent circulating pump.

BOILER FEED SYSTEM.

The two main feed pumps are in the engine room and the two auxiliary feed pumps in the fire room. As there is but one feed heater, the discharge piping is arranged so as to permit both the auxiliary and main feed pumps to discharge through the same heater. The main feed pumps take suction from the feed tank, located just abreast and above them, the air pump channel way, and the reserve bottoms. The auxiliary feed pumps take suction from the feed tank, reserve bottoms, boiler blowpipes, and from a connection to the ship's side. The feed tank has a capacity of 1700 gallons.

FEED HEATER DATA.

Type	horizontal surface
Number	1
Location	engine room
Number of tubes	270
Diameter of tubes, outside, inch	⅝
Thickness of tubes	18 B.W.G.
Length of tubes as fitted, feet and inches	7–3⅝
Square feet of heating surface	309

PROPELLER AND SHAFTING.

There are three sections of line shafting carried on six bearings. Each section is 16⅝ inches in diameter, has a 7½-inch bore and is 23 feet 6 inches long. The stern tube and propeller shaft, carried on two bearings is 17½ inches in diameter and 26 feet ⅜ inches long. The stern tube casting required running a heat of approximately eight tons of cast steel.

PROPELLER DATA.

Number, type, and material; one right hand; hub, cast steel; blades Mn-c.	
Number of blades	4
Diameter, feet and inches	16–6
Pitch as set, feet and inches	18–3 15/16
Pitch adjustable from, feet and inches	17–4 to 19–4
Ratio of diameter to pitch (as set)	.90
Projected area, square feet	90.31
Disc area, square feet	213.9
$\frac{\text{P. A.}}{\text{D. A.}}$	.422
Height of lower tip of blade above keel, inches	17
Immersion of upper tip of blade (at load draft), inches	8⅛

FORCED-DRAFT BLOWERS.

Two horizontal turbine-driven blowers, located in separate compartments just above, and on either side of the fire room, take suction, through trunks leading directly to the bridge deck, and deliver air through openings located just above the after, upper working gratings in the fire room. There is a hand steam control, for each blower, in each blower room and in the fire room.

BLOWER DATA.

Maker	Terry Steam Turbine Co., Hartford, Conn.
Number and type	2–Z2
Capacity	30,000 cubic feet per minute against head of 4½-inch water.
Type fan	Keith No. 25
Horsepower, normal R. P. M	44
Revolutions per minute, normal	1500
Revolutions per minute, test speed	1875
Steam pressure, pounds per square inch	215

RECIPROCATING PUMPS.

Use	No.	Location	Cylinder Diameter		Stroke	Maker
			Steam	Water		
Main air	1	E. R.	14	2–28	18	Blake-Knowles
Main feed	2	E. R.	10	6	12	Blake-Knowles
Auxiliary feed	2	F. R.	10	6	12	Blake-Knowles
Fire and bilge	3	1 E. R.; 2 F. R.	12	14	16	Dow-Diesel
Flushing	1	E. R.	12	14	12	Dow-Diesel
Auxiliary air and circulating	1	E. R.	6	2–8	8	Epping-Carpenter
Dynamo air	1	E. R.	9	18	12	Davidson
Fuel oil supply	1	F. R.	7½	8½	8	Dow-Diesel
Fuel oil service	2	F. R.	7½	4½	10	Blake-Knowles
Lubricating oil	3	E. R.	8	10	12	Blake-Knowles
Oil cooler circulating	2	E. R.	7	8	12	Blake-Knowles
Ice machine condenser circulating	2	Ice mach. room	4½	6	6	Davidson
Cargo lubricating oil	1	F. R.	3½	4	4	Worthington
Ice machine brine	2	Ice mach. room	4½	6	6	Davidson

CENTRIFUGAL PUMPS.

Use	No.	Location	Capacity g. p. m.	Head feet	Drive		Maker
					Motor	Reciprocating	
Distiller circulating	2	Evap. room	800	40	M	...	Buffalo Steam Pump
Evaporator brine overboard	2	Evap. room	50	72	M	...	Buffalo Steam Pump
Distiller fresh water	2	Evap. room	50	72	M	...	Buffalo Steam Pump
Evaporator brine circulating	6	Evap. room	200	16	M	...	Buffalo Steam Pump
Fresh water distributing	2	Evap. room	...	...	M	...	Erie Pump Co.
Distiller condensate	2	Evap. room	50	42	M	...	Davidson
Main circulating	1	Engine room	10,000	...	...	11 × 12	Navy Yard
Dynamo circulating	1	Engine room	...	...	...	5 × 5	Navy Yard
Laundry drain tank overboard	2	Fire room	...	...	M	...	....
Hot water distributing	1	Air comp. room	50	60	M	...	Northern Elec. Mfg. Co.

Exhaust pressure, maximum allowed, gauge	15
Number of nozzles	6
Size of nozzles, throat, diameter	5/16
Type of governor	Fly ball
Lubrication	reservoirs with oil rings
Direction of rotation	1 clock, 1 counter clock

FUEL OIL APPARATUS AND SERVICE.

The fuel oil apparatus is similar in nearly all respects to the type generally installed on Naval vessels. The seven natural draft registers, per boiler, are mounted in two rows, four in the lower, and three in the upper. Each register, provided sufficient air is supplied, has a maximum capacity of 1200 pounds of fuel per hour. The Bureau of Engineering standard tips and plugs, sizes as required for the various conditions of steaming, will be used.

In lieu of the booster pumps ordinarily installed, there is one supply pump, which, in addition to feeding the two service pumps, can be used for transferring oil and for discharging overboard.

There is not a central control manifold, in the fire room, for the fuel oil tanks, so individual tanks must be cut in or out of the main line by using the valves located in the vicinity of the tanks.

The service pumps discharge, through air chambers, to the oil heater, and thence to the service lines feeding the atomizers. Special arrangements, by installing an extra large amount of heating surface in the fuel oil tanks, have been made for handling cold, heavy oil.

OIL HEATER DATA.

Type	surface straight tube
Number	1
Location	fire room
Number of tubes	92
Thickness of tubes, mils	65
Outside diameter of tubes	5/8
Length of tubes as fitted, feet and inches	4–2¼
Heating surface, square feet	60.214

WEIGHT HANDLING.

Both masts are fitted with booms; these principally for boat and cargo uses.

Practically all repair work will be handled by the booms carried on the four boom posts located amidships on the main deck.

Two of these boom posts are fitted with one 20-ton and one 10-ton boom each, and two boom posts are fitted with one 8-ton boom each.

Each mast has two 8-ton booms.

The booms will reach 20 feet clear of the side, and plumb all hatches in the well. Twenty tons can be handled.

The machine shop and foundry are provided with large electric traveling cranes, and the other shops with weight handling facilities according to the work they may be expected to handle.

DECK WINCHES.

There are sixteen deck winches, right and left-hand control, having drums with both direct and friction drive, located as follows:

LIST AND LOCATION OF DECK WINCHES.

Winch No.	Location		Frame	Right or Left	Remarks
	Deck	P. or S.			
1	Super	S	120	Left	Friction Drive
2	Super	P	120	Right	Friction Drive
3	Super	S	122	Right	Friction Drive
4	Super	P	122	Left	Friction Drive
5	Forcl.	S	28	Left	Direct Drive
6	Forcl.	C	26	Right	Direct Drive
7	Main	S	54	Left	Friction Drive
8	Main	P	54	Right	Friction Drive
9	Main	S	69	Left	Direct Drive
10	Main	P	69	Left	Direct Drive
11	Main	S	73	Right	Direct Drive
12	Main	P	73	Left	Direct Drive
13	Main	S	75	Left	Direct Drive
14	Main	P	75	Right	Direct Drive
15	Main	S	80	Right	Friction Drive
16	Main	P	80	Right	Friction Drive

These winches were built by the Lidgerwood Manufacturing Co. of New York, and are of two types. Eight winches have direct-driven drums where the drum is keyed fast to a drum shaft 4⅛ inches in diameter, and driven through a single reduction of semi-steel gearing having machine moulded teeth. Fitted onto a flange of the drum is a powerful band brake, having non-burn lining, capable of holding a load of 10,000 pounds without the use of steam. This brake is operated by a foot lever located conveniently for the operator. The drum shaft is extended on the gear side, and a winch head 14 inches in diameter is keyed fast to the end. The bed plate has heavy side frames with drum shaft bearings 7 inches long with oil save-alls cast integral with the bed. These winches are all made to gauge, and parts may be replaced with a certainty of accurate fitting.

The eight winches of the friction drum type are similar in general construction, except that the drum instead of being keyed direct to the shaft, is driven through a friction of the double cone type fitted with wood having cork inserts. The winches of both types have powerful band brakes on the drum flange with throttle, friction levers and foot brake lever all within convenient reach of the operator.

These winches have 8¼ inches by 8 inches cylinders, drums 16 inches diameter and 14 inches and 20 inches long, one 14 inches by 14 inches gypsy head, and are operated by the lever of the reversing valve.

BOATS AND BOAT HANDLING.

Complement Of Small Boats

Name of Boat	No. on Ship	Length	Hoisting Weight Each	Carrying Capacity One Boat
Motor Sailing Launch.....	2	40 feet	14091	90 Men
Motor Sailing Launch.....	2	36 feet	12429	70 Men
Motor Sailing Launch.....	2	24 feet	6230	19 Men
Motor Boat.....	2	35 feet	10734	27 Men
Whaleboat.....	2	30 feet	5888	40 Men
Dinghies.....	2	16 feet	968	10 Men
Punts.....	2	14 feet	831	.....

The two 30-foot whaleboats are located on the bridge deck forward, at frames 39-49 port and starboard, and swing from Navy Standard type davits located just forward of frames 40 and 50. Chocks are fitted for landing the boats inboard on the deck when necessary.

The boats are hoisted and lowered through a purchase from the falls to the steam winches on the main deck leading through snatch blocks at the foot of the davits and rollers at the break of the forecastle to the gypsy heads on the winch. All winches for handling boats are steam-driven "Lidgerwood Manufacturing Co.'s" single friction drum type, especially designed for heavy duty and working at 125 pounds steam pressure. The cylinders on these winches are of the piston valve type, designed to withstand a maximum steam pressure of 200 pounds, the cylinder walls being one inch thick. The friction drum is of the double cone type, the wood having cork inserts. The drum has extra deep and heavy flanges and is equipped with a non-burn lined band brake on the drum flange operated by a foot lever with detent.

The throttle and friction levers and foot brake lever with detent are all conveniently located so that the winches may be handled for fast handling as well as for heavy duty.

The winch head is 14 inches diameter through the body, 20 inches diameter over the flanges and 14 inches in length, and is keyed to the end of the drum shaft.

The motor sailing launches, 35-foot motor boats, and 16-foot dinghies are all stowed on the superstructure deck, and are handled by Stewart patented davits or booms provided for the purpose. The 36-foot and 24-foot motor sailing launches are provided with Stewart patented davits, and the 40-foot motor sailing launches and the 35-foot motor boats are handled with booms provided for the purpose and stepped on the mainmast at frame 121.

Four friction drum type steam winches with gypsy head are provided on the superstructure deck at frames 119-121, 121-123 starboard, and 121-123 port, for handling the boats on this

deck. The winches are the same as fitted on the main deck forward for handling the 30-foot whaleboats.

The purchases, 3½-inch manila, for the 24-foot motor sailing launches and 4-inch manila for the 40-foot motor sailing launches, are led from the davits through snatch blocks on deck to the gypsy heads on the winches.

BOOMS.

Two 16,000-pound steel booms 50 feet long and stepped on the mainmast, one on the forward side for handling 40-foot motor sailing launches and one on the after side for handling the 35-foot motor boats, are provided. The hoist on these booms is a three-part purchase consisting of ¾ inch diameter, type AA, plough steel wire rope passing through single blocks having sheaves 18 inches in diameter, with fixed end secured to the lower or hoist block. The purchase from both booms leads through sheave blocks at the base of the mast, that from the forward boom to the friction drum on the starboard forward winch, and that from the after boom to the friction drum on the port after winch.

The topping of these booms is accomplished through a four-part purchase consisting of ⅞ inch diameter, type AA, plough steel wire rope passing through blocks having 18-inch diameter sheaves to the winches on deck, the lead for topping the forward boom passing to the friction drum of the port forward winch and that for topping the after boom to the friction drum on the starboard after winch. Two four-part purchases, consisting of 3½-inch manila rope and standard 10-inch single and double blocks, are provided for swinging each boom. Leads to the gypsy heads are provided by fitting standard snatch blocks where necessary to insure fair leads.

STORE ROOMS.

Special attention has been given to providing adequate storerooms. These are all large and well equipped with bins and shelves for proper stowage.

GASOLINE STOWAGE.

There are no gasoline storage tanks; such gasoline as is carried will be stowed in drums, carried on the forecastle deck.

LUBRICATING OIL STOWAGE.

Four tanks, having a capacity of 140 tons, will carry lubricating oil. A small reciprocating pump located in the fireroom is used for transfer.

COMPRESSED AIR.

Directly opposite the ice machine room, on the starboard side, is the main air compressor room.

AIR COMPRESSOR DATA.

Type.....Ingersoll-Rand, two stage, Imperial, Number 10
Working pressure, pounds per square inch..... 110
Size: right hand steam..... 10 by 14
right hand air..... 16 by 14
left hand steam..... 10 by 14
left hand air..... 10 by 14
Revolutions per minute..... 185
Accumulators: 2 tanks of ½-inch plate, 3 feet 6 inches in diameter by 9 feet high, mounted vertically.

From these compressors, a pneumatic main extends through the shop spaces, supplying air for operating pneumatic tools in the shops, furnaces in the foundry, coppersmith shop and blacksmith shop; torches in the foundry, coppersmith and blacksmith shop. In each shop distributing manifolds can be installed, as found necessary, on the permanent outlets. For portable connections, 500 feet of air hose, in 10-foot lengths, with all necessary fittings, is supplied.

GALLEY AIR COMPRESSOR.

For supplying air to the galley there is, located in the air compressor room, one Allis-Chalmers direct connected, motor driven, single stage air compressor of the intermittent type. At 1100 R.P.M. this has a capacity of 50 cubic feet, delivering air at 80 pounds per square inch. The control is automatic.

HUMIDIFIER COMPRESSOR.

One motor driven, single stage compressor, located in the air compressor room, furnishes the compressed air for the operation of the humidostat used in regulating the humidifying steam for the mechanical, blast, heater system.

GAS EJECTOR AND SHIPS SERVICE COMPRESSORS.

For the gas ejector system and ship's service, such as blowing tubes, etc., there are two Westinghouse single stage, steam driven compressors, 11 by 11 by 12. The two accumulators provided for these compressors are interconnected with the large accumulators of the main system.

FRESH WATER SUPPLY.

The reserve feed tanks, six in number, have a capacity of 476 tons. For ship's use there are four tanks, having a capacity of 184 tons. Two motor driven pumps, located in the evaporator room, furnish fresh water to a 1,000-gallon fresh-water tank, and from there the water is distributed by gravity throughout the ship. All shops are well provided with outlets both for use in conjunction with repair work and for washing purposes. In addition to the cold water supply, there is a fresh hot-water system; this consists of a Navy standard hot-water heater having both live and exhaust steam connections, and an automatic thermostatic control. Distribution is effected by a motor-driven centrifugal pump having a capacity of 50 gallons per minute.

DISTILLING PLANT.

The evaporator room and distiller room are located in a separate compartment, just abaft the engine room; the distilling condenser being located well above the evaporators.

This plant is of the latest Bureau of Engineering Low Pressure type; and has a normal rated capacity of 40,000 gallons: the test capacity is 52,000 gallons per 24 hours. There are six shells arranged athwartships, three in each side of the center line, the first effect shells being outboard on either side.

Each shell has its own brine circulating pump; there are two brine overboard discharge pumps. The distiller circulating pump is used for feeding purposes.

The vacuum system consists of two condensate pumps, so piped that either one or both can be used at the same time, for removing the condensate from the distilling condensers, and at the same time removing the drainage from the flash chamber; and two air ejectors for removing air from the distilling condensers. The air ejectors discharge to a cooling condenser, located just below the distilling condensers. This is the first plant installed, on board a Naval vessel, with condensate pumps and air ejectors.

The condensate pumps deliver the water to a measuring tank, and from there it is distributed by two rotary, motor-driven pumps.

All pumps in the evaporator room are motor driven.

DISTILLING CONDENSERS.

Number	2
Location	distiller room
Number of tubes	610
Mean length of tubes, feet and inches	4–7
Outside diameter of tubes, inch	5/8
Thickness of tubes, mils	65
Thickness of shell, inch	5/8
Tubes expanded both ends.	
Double pass.	
Thickness of tube sheet, inches	7/8
Cooling surface, square feet	458

EVAPORATOR FEED WATER HEATER.

Number	1
Location	distiller room
Type	curved tube
Tubes expanded, both ends.	
Heating surface, square feet	50
Number of tubes	78
Thickness of tubes, mils	65
Outside diameter of tubes, inch	⅝

REFRIGERATION.

Located on the third deck, abaft the engine room bulkhead, the cold storage compartments take up the greater part of the space between frames 120 and 129. There are six separate compartments and two vestibules. Access to the main meat and officers' storage rooms can only be gained through a vestibule; the butter compartment can be entered direct. The compartments are: meat room on the port side; butter and egg room on the starboard side; captain's, warrant officers', wardroom officers' and chief petty officers', amidships and abaft the meat room vestibule. The main meat room has a capacity of 3743 cubic feet; the butter and egg room, 2504 cubic feet; and the officers' storage rooms, 913 cubic feet.

Cooling is accomplished by two 6-ton American Carbonic Machine Company's CO_2 machines, located on the port side of the third deck, forward of the boiler room bulkhead, frame 97. The ice machine room is well laid out, there being plenty of space, and contains the following:

2—6-ton American Carbonic Machine Co. steam-driven units, size 4⅛ by 6.
1—50-gallon brine storage tank.
2—6-ton brine coolers.
1—40-gallon brine mixing tank.
2—4½ × 6 × 6 condenser circulating pumps.
2—4½ × 6 × 6 brine circulating pumps.

3—200-pound ice-making tanks, 9 cans to a tank.
1—melting tank.
1—1½ inch condenser.
1—250-gallon lubricating oil tank.

From the ice machine room, connections are had direct to two scuttle butts, one located in the crew's compartment aft, and the other on the gallery in the machine shop.

Water for the ice-making tanks is obtained from a line leading from the scuttle butts.

SICK BAY.

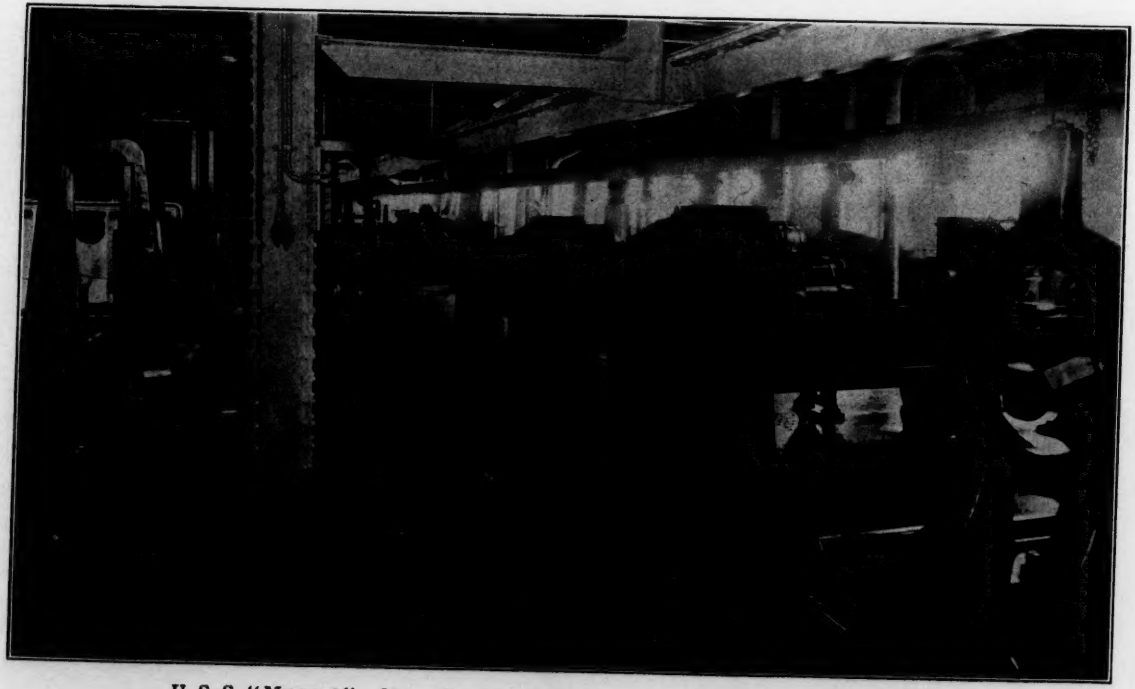
Every provision possible is made for handling the sick. On the main deck, the entire space between frames 12 and 24 is given over to the medical department. There is, fully equipped, a sick bay, diet kitchen, operating room, dispensary, examining room, bath and closet, isolation ward, and a treatment room.

TOWING MACHINE.

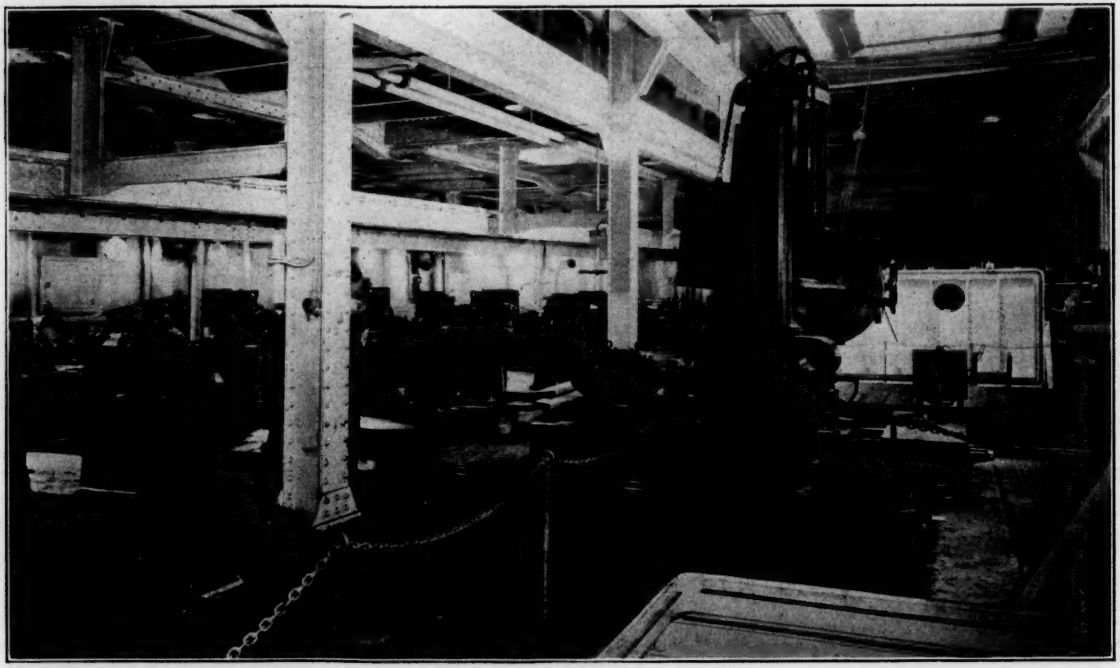
The towing machine is known, commercially, as the "Philadelphia Combined F Towing Machine and Mine Sweeper" and was manufactured by the American Engineering Company of Philadelphia, Pa. The winding drum is 36 inches in diameter and 51 inches long, and is capable of holding 300 fathoms of 7-inch steel wire rope. The machine is built for automatic towing under all conditions of weather.

Two gypsy heads, 21 inches in diameter, are fitted on extended shafts, and are available for warping purposes. The cylinders are 18 inches in diameter and 20 inches stroke, and designed for a working pressure of 125 pounds per square inch.

The machine is fitted with a reverse valve which may be operated by hand or by means of an automatic control. The winding attachment is driven from the drum shaft through a double set of steel mitre gears and consists of two vertical rolls



U. S. S. "MEDUSA". MAIN MACHINE SHOP, STARBOARD SIDE, LOOKING FORWARD.



U. S. S. "MEDUSA". MAIN MACHINE SHOP, PORT SIDE, LOOKING FORWARD.

mounted on a cast iron carriage which moves back and forth to lay the towing cable evenly on the drum by means of a swiveling nut and lead screw with right and left hand threads.

MACHINE SHOP.

The main machine shop is located on the third deck, and occupies the entire space between frames 36 and 74. In addition, there is the gallery machine shop and tool machine shop, taking up the port side of the second deck between frames 36 and 74.

The machine shop bay is 33 frames fore and aft, and 5-frame lengths athwartships. This bay is plumbed by two large hatches. At the forward end of the gallery machine shop is the shop office, and at the after end, abaft the electrical shop, there is a large and commodious wash room for the repair force.

On the gallery is a shop tool and supply room, and a storeroom.

For weight handling there are two 2-ton double beam electric traveling cranes and one 3-ton double beam electric crane; these cranes being capable of traveling the full length of the shop.

MACHINES.

1—42-inch vertical boring and turning milling machine; Gisholt Mach. Co., Reliance Motor, 10 H.P.

1—73-inch vertical boring and turning milling machine; Niles Bement Pond, General Electric Motor, 12½ H.P.

1—60-inch by 7-foot low-bed boring, drilling and milling machine; Bethlehem Steel Co., General Electric Motor, 12½ H.P.

1—60-inch by 7-foot high-bed boring, drilling and milling machine; Niles Bement Pond, General Electric Motor, 10 H.P.

1—10-inch by 1-inch double bench buffing machine; Cincinnati Tool Co., Motor same, 1 H.P.

1—½-inch to 6-inch—2-spindle centering machine; D. Nast Mach. Co., Reliance Motor, ¾ H.P.

3—24-inch—3-jaw chuck columns.

1—3-ton double beam traveling crane; Pawling & Harnischfleger Co. Motors, 6 H.P.

2—2-ton double beam traveling cranes; Pawling & Harnischfleger, Motors same.

1—4-inch by 12-inch cylinder boring machine; H.P. Underwood Corp., Reliance Motor, 1½ H.P.

1—12-inch by 30-inch cylinder boring machine; H.P. Underwood Corp., Reliance Motor, 3 H.P.

1—30-inch by 100-inch cylinder boring machine; H.P. Underwood Corp., Reliance Motor, 10 H.P.

4—12-inch bench drills; Jas. Clarke, Jr., Co., Motors, ⅓ H.P.

1—22½-inch sliding head drill press; Fairbanks Co., Reliance Motor, 2 H.P.

1—28-inch sliding head drill press; Fairbanks Co., Reliance Motor, 2 H.P.

1—4-foot radial drill press; W. E. Shipley Mach. Co., General Electric Motor, 5 H.P.

1—36-inch gear cutting machine; Kemp Mach. Co., Reliance Motor, 5 H.P.

2—14-inch by 1½-inch combination floor type wet and dry grinders; Manning, Maxwell & Moore, Reliance Motors, 1½ H.P.

1—16-inch by 2-inch wet grinder; Kemp Mach. Co., Clarke Motor, 2 H.P.

2—12-inch by 2-inch bench grinders; Hisey Wolf, H. W. Motors, 2 H.P.

1—10-inch by 40-inch universal high-power grinder; D. Nast Mach. Co., Reliance Motor, 3 H.P.

1—No. 3 universal grinder; Brown & Sharpe, Reliance Motor, ¾ H.P.

10—14-inch by 8-foot engine lathes; Whitcomb Blaisdell Mach. Co., General Electric Motors, 1½ H.P.

1—16-inch by 8-foot engine lathe; Whitcomb Blaisdell Mach. Co., General Electric Motors, 3¾ H.P.

4—16-inch by 12-foot engine lathes; Whitcomb Blaisdell Mach. Co., General Electric Motors, 3¾ H.P.

2—18-inch by 12-foot engine lathes; Whitcomb Blaisdell Mach. Co., General Electric Motors, 3¾ H.P.

2—24-inch by 14-foot engine lathes; Fairbanks Co., Reliance Motor, 10 H.P.

1—28-inch by 48-inch by 14-foot gap lathe; Rahn Larmon Co., General Electric Motor, 7½ H.P.

1—48-inch by 72-inch by 15-foot 3-inch gap lathe; D. Nast Mach. Co., Westinghouse Motor, 20 H.P.

2—8½-inch by 22-inch cabinet bench lathes; Fairbanks Co., Reliance Motor, 1 H.P.

1—12-inch by 6-foot toolmakers screw cutting lathe; Fairbanks Co., Reliance Motor, 1 H.P.

1—⅝-inch by 4½-inch turret lathe; Pratt & Whitney, General Electric Motor, 1 H.P.

1—2¼-inch by 26-inch turret lathe; Manning, Maxwell & Moore, General Electric Motor, 5 H.P.

1—36-inch vertical turret lathe; Fairbanks Co., Reliance Motor, 10 H.P.

1—24-inch vertical turret lathe; Fairbanks Co., Reliance Motor, 7½ H.P.

1—No. 1, 22-inch universal milling machine; Fairbanks Co., Reliance Motor, 2 H.P.

1—No. 2, 28-inch universal milling machine; Fairbanks Co., Reliance Motor, 3 H.P.

2—No. 3, 34-inch universal milling machines; Fairbanks Co., Reliance Motor, 5 H.P.

2—No. 4A, 42-inch universal milling machines; Brown & Sharpe, Reliance Motor, 10 H.P.

1—36-inch by 24-inch by 8-foot open end planer; Detrick Harvey Co., Reliance Motor, 7½ H.P.

1—30-inch by 30-inch by 6-foot planer; Niles Bement Pond, Pond Motor, 7½ H.P.

1—36-inch hand arbor press; Kemp Mach. Co.
1—12-inch bench hand arbor press; Manning, Maxwell & Moore.
1—100-ton hydraulic forcing press; Watson Stillman Co., General Electric Motor, 3 H.P.
1—26-inch cold metal cut-off saw; Vandyck Churchill Co., General Electric Motor, 5 H.P.
1—8-inch by 15-inch power hack saw; W. Robertson Mach. Co., General Electric Motor, ½ H.P.
2—16-inch high-duty crank shapers; D. Nast Mach. Co., Reliance Motor, 3 H.P.
2—25-inch high-duty crank shapers; D. Nast Mach. Co., Reliance Motor, 5 H.P.
1—24-inch double spindle shaper; Oliver Mach. Co., General Electric Motor, 7½ H.P.
1—10-inch slotter; Niles Bement Pond, General Electric Motor, 5 H.P.
1—125-ton hydraulic shaft straightener; Hallidie Mach. Co.

The above equipment embodies nearly every type of machine necessary in the prosecution of marine machinery repair work. All machines are motor driven and of the latest type. For handling the general run of repair work, this shop is as well equipped, and better in certain respects, as any navy yard in the country.

As an illustration of the work that may be handled a few specific instances are set forth.

The large gap lathe, 48 inches by 72 inches by 183 inches, will handle any turbine under six feet in diameter and fifteen long. By the use of steady rests, the average length of shafting can be handled.

The vertical boring mills, 72 inches and 42 inches, respectively, can be used for boring out pump liners, turning cylinders, piston rings and pistons, bearings, flanges, and gears.

The large boring mill, 60 inches by 7 feet, can be used for boring large cylinders, turbine casings, and for milling work

that is too large for the milling machines, such as keyways in large shafting.

The 36-inch gear cutting machine can be used for cutting worms, helical and spur gears.

OPTICAL SHOP.

The optical shop, extending practically across the ship, and between frames 34 and 50, is located on the forecastle deck. The shop is divided into two main compartments by a fore and aft bulkhead pierced with window and door openings. The port side is designated as the optical repair shop, and has at its after end two enclosed spaces, designated respectively as the gyro repair shop, and the laboratory. The starboard side, extending the full distance between frames 34 and 50, is called the assembly shop. Both the assembly and repair shop have large bench space and cabinet space. The following equipment is installed:

1—10-inch engine lathe; Pratt & Whitney.
1—12-inch engine lathe; Pratt & Whitney.
1—watch-maker's lathe on cabinet; F. W. Derbyshire.
1—bench lathe; Elgin Tool Works.
1—vertical bench milling machine; D. Nash & Co.
1—No. 1 milling machine; Cinn. Milling Mach. Co.
1—bench drill; Winterhoff Tool & Mach. Co.
1—bench grinder; Neil & Smith.
1—optical grinder; L. Best & Co.

FOUNDRY.

The foundry, located on the third deck, consists of three bays, taking in the entire width of the ship, and extending between frames 74 to 90. The main bay is well lighted and ventilated by means of a skylight; the lighting and ventilating of the side bays is amplified by large ports.

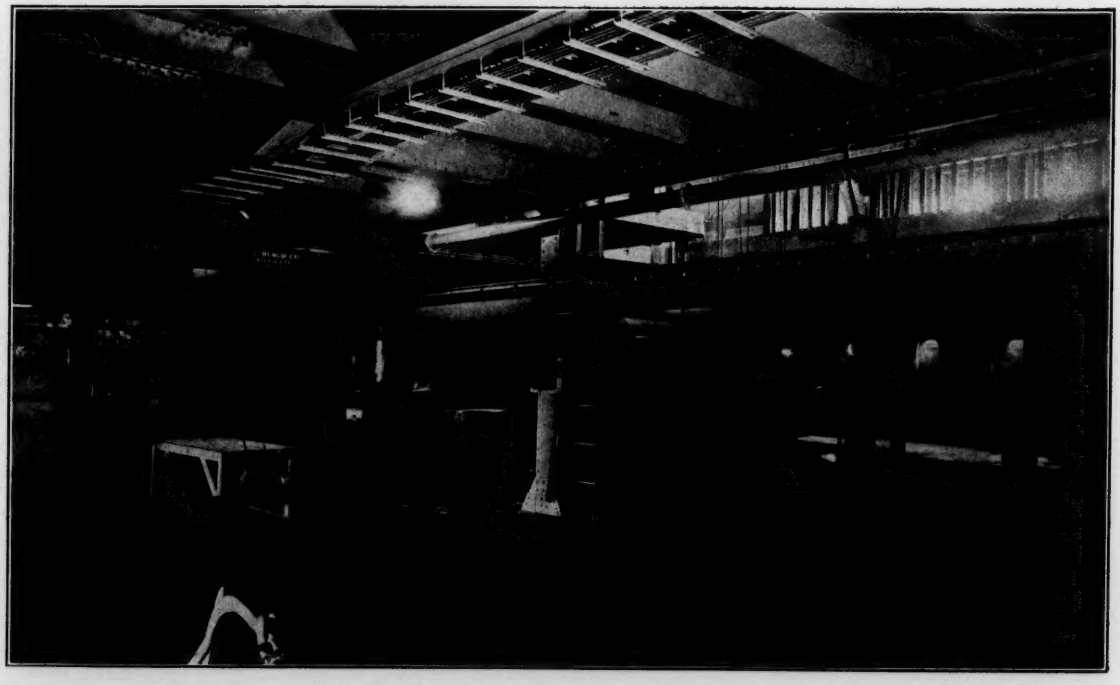
In the iron foundry, there is a 32-inch cupola capable of melting about four tons of iron per hour, and an 18-inch one that will melt about 1½ tons per hour. When light castings

are required or when the tonnage is light, the small cupola will be used and when the tonnage demands, the large one will be operated. It will also be possible to use both cupolas if necessary; in this event, a single casting weighing several tons can be successfully run. A three-ton electric traveling crane serves the cupolas which are at opposite ends of the main bay; this crane also serves a molding space, approximately 20 by 24 feet, where the large and heavy work will be molded and cast. The crane will also handle the molding sand and pig-iron from the stowage room located below the foundry main deck.

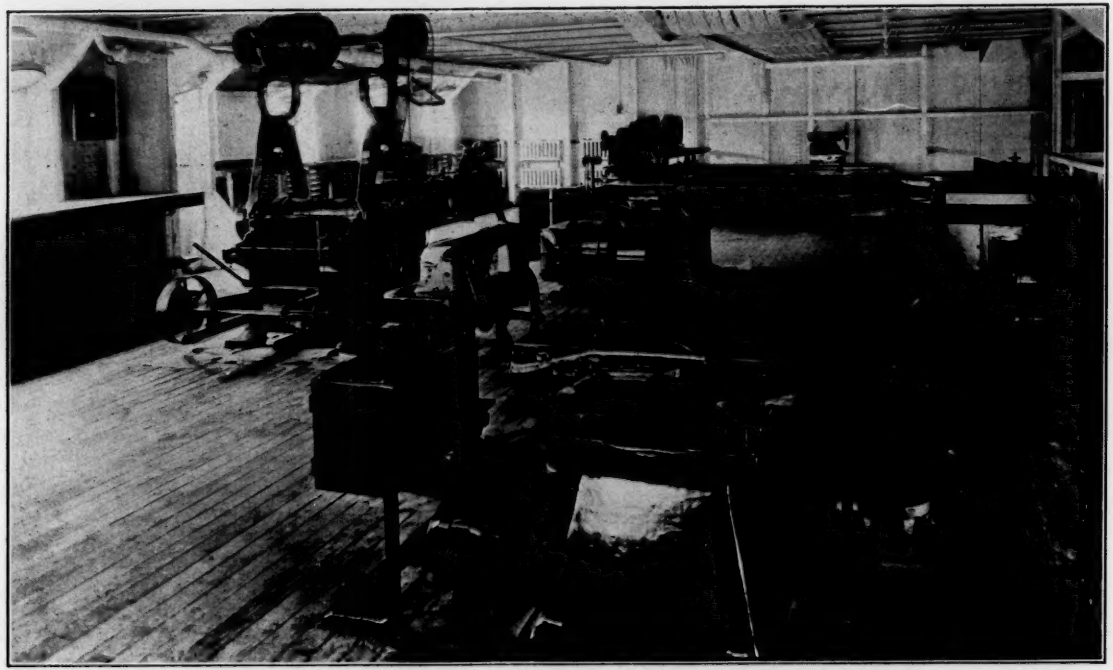
The upper deck of the foundry does not cover the main bay, thus leaving plenty of head room. It does, however, cover the side bays, forming a mezzanine floor. Part of this floor forms an ideal charging platform for the cupola; it is the correct height and extends into the main bay at one end, forming a receiving platform for pig-iron and scrap metal. The coke stowage is on this floor, convenient to the cupola. One side of this deck, directly over the side bay, is used for flask stowage, the opposite side makes a well lighted and ventilated core-making room for small cores. A metal core-maker's bench extends the length of the space in front of the ports, and an oven heated by electricity is installed for drying cores. There is also a larger electric oven, on the main deck of the foundry, in which the large cores and molds may be dried or baked. These ovens have cars with tracks extending into the shop.

One side bay on the main floor or deck contains the chipping and cleaning room with the following equipment; chipping benches, vise, bins, weighing scale, a set of grinding wheels, a tumbling barrel with dust exhaust, a metal cutting band saw for removing non-ferrous gates and risers and a magnetic separator for removing iron and steel from the brass borings and turnings. At the end of this bay there is also a metal storage locker room for brass foundry metals.

In the main bay, adjacent to the large cupola, there are four oil-fired, tilting, brass-melting, crucible furnaces for melting brass, bronze and other non-ferrous metals. These furnaces



U. S. S. "MEDUSA". FOUNDRY, LOOKING TO PORT.



U. S. S. "MEDUSA". PATTERN SHOP, PORT SIDE, LOOKING FORWARD.

have a maximum capacity of 600 pounds each and when the battery of four are operated at one time, a one-ton casting might easily be run. Should it be found necessary to cast a large bronze propeller wheel blade while at sea, this could be accomplished by using the iron cupola alone or in conjunction with the brass furnaces.

There are two molding tubs, to be used for small molds, at the end of this floor. Several small shank ladles are provided for pouring the light work, and three crane ladles of ½, 1½, and 3 tons capacity for pouring the heavy work.

The other side-bay is served by one-ton electric traveling crane; this bay has a molding space of approximately 25 feet by 35 feet area to be used in making light floor molds and heavy cores. In this bay is found the large core and mold-drying oven previously mentioned. Here is also located a Root's Positive Pressure Blower No. 4, which furnishes the blast for the cupolas and brass furnaces.

With the space and equipment provided, it is possible to make large quantities of small and medium size castings in iron, brass or bronze, and large castings weighing several tons. In short, most of the ordinary run of castings needed on a ship, or castings that are liable to break in service, can be handled.

EQUIPMENT.

1—Centrifugal blower, 3200 cubic feet per minute; P. H. and F. M. Roots Co.; General Electric Motor, 20 H.P.

1—3-ton double beam traveling crane; J. C. Busch Co.; P. & H. Motor, 3 H. P.

1—Iron cupola, 3- to 5-ton capacity; Whiting Foundry and Equipment Co.

1—Iron cupola, 1-ton capacity; Whiting Foundry and Equipment Co.

4—Oil burning brass tilting furnaces, 700 pounds capacity each; Monarch Eng. and Mfg. Co.

1—16 by 2 Double bench grinder; Hisey Wolf, H. W. Motor, 3 H.P.

1—3-ton geared crane ladle; Whiting Foundry and Equipment Co.

1—1½-ton geared crane ladle; Whiting Foundry and Equipment Co.

1—½-ton geared crane ladle; Central Foundry and Sup. Co.

1—Electric core baking oven, 7 feet by 7 feet, 6 inches by 7 feet 10 inches; Westinghouse Electric Co.

1—Electric drying oven, 7 feet by 7 feet, 6 inches by 7 feet 10 inches; Westinghouse Electric Co.

1—26-inch metal band saw; Monarch Mach. Co., G. E. Motor, 1 H.P.

1—8000-pound suspension crane scale; Meyer Scale and Hardware Co.

1—Magnetic separator, capacity 300 pounds per hour; Magnetic Manufacturing Co., Westinghouse Motor, 1 H.P.

1—30 by 36 foot tumbler; Whiting Foundry and Equipment Co., General Electric Motor, 5 H.P.

PATTERN AND JOINER SHOPS.

The pattern and joiner shops are located on the port and starboard sides, respectively, of the second deck, between frames 90 and 103. Each shop has a floor space of approximately 1365 square feet. The two shops are connected by passageways, forward and aft of the hatch space separating them. With this arrangement, each shop can make use of all the machines in both shops.

The equipment, which is of the highest grade and latest model, includes the following machines:

Machine.	*No.*	*Manufacturer.*	*Size Motor.*
Bench grinder, 12 by 12.	2	Hisey Wolf.	2 H. P.
Arbor grinding oil stone, 10 by 2½ with 30-inch knife grinding attachment.	1	J. A. Fay & Eagen.	1 H. P.
Pattern makers lathe, 24 by 8.	1	Oliver Mach. Co.	2 H. P.

Machine.	*No.*	*Manufacturer.*	*Size Motor.*
Gap lathe, extension type, 30 by 60 by 15.	1	Oliver Mach. Co.	5 H. P.
Universal mortiser.	1	Fay and Eagen.	5 H. P.
Planer and jointer table, 6 by 24.	2	Oliver Mach. Co.	1 H. P.
Planer and jointer table, 24 by 64.	1	Oliver Mach. Co.	5 H. P.
Vertical sanding machine, 30-inch.	1	Oliver Mach. Co.	2 H. P.
Band saw, 38-inch.	1	D. Nash & Co.	3 H. P.
Variable speed surfacer, 26 by 8.	1	Manning, Maxwell and Moore.	7½ H. P.
Saw table, 26-inch.	1	Oliver Mach. Co.	7½ H. P.
Hand bench trimmer, 8-inch stroke.	2	Oliver Mach. Co.	
Universal floor type trimmer, 15-inch.	1	Oliver Mach. Co.	

In addition to the above machines, there is provided a very large amount of bench space, the benches being equipped with the necessary hand tools and fixtures. The machines are well spaced, thus affording every facility for the handling of work.

The equipment provided is equal to, and probably better than, that installed in the majority of industrial establishments operating in the production of gray iron castings.

With proper mechanics available, the equipment will permit of the handling of all sorts of repair and replacement work, such as occurs on distillers, auxiliaries, valves, fittings, boats, engine parts, etc. Not only can all such jobs be handled expeditiously, but with the excellent arrangement, numerous jobs can be prosecuted without interference, at the same time.

BLACKSMITH AND BOILER SHOPS.

These two shops constitute practically one shop, being located on the main deck, just aft of the center well, and occupying the space between frames 90 and 120. The combined shops are roomy and accessible to the weight handling booms of the center well. For weight handling in the shop proper, there are two portable tracks, arranged in loops; one loop encircling

the entire shop, and the other loop serving the forward end of the shop. In addition, there are eight 1000-pound jibs located in various parts of the shop.

Fifty-six oxygen and acetylene tanks, mounted throughout the shop, are furnished for cutting and welding.

EQUIPMENT.

2—7-foot by 14-foot double-faced bending slabs; P. S. Navy Yard.

1—centrifugal blower for oil forges; P. H. & F. M. Roots Co., G. E. motor, 25 H.P., blower capacity 900 cubic feet.

1—1-ton double beam traveling crane; J. C. Busch Co., motor, 3 H.P.

2—½-inch electric cranes, monorail type; Pawling & Harnischfleger Co., motors same, 2 H.P.

8—½-ton pneumatic geared hoists jib cranes; Detroit Hoist & Mach. Co.

1—22½-inch sliding head drill press; Fairbanks Co., Reliance Motor, 2 H.P.

1—4-foot radial drill; Niles Bement Pond, Westinghouse Motor, 5 H.P.

1—oil-burning bench forge; Tate Jones Co.

4—oil-burning blacksmith forges; Tate Jones Co.

1—oil-burning ingot forging furnace; Tate Jones Co.

1—oil-burning annealing furnace; Mircs Fuel Oil Equipment Co.

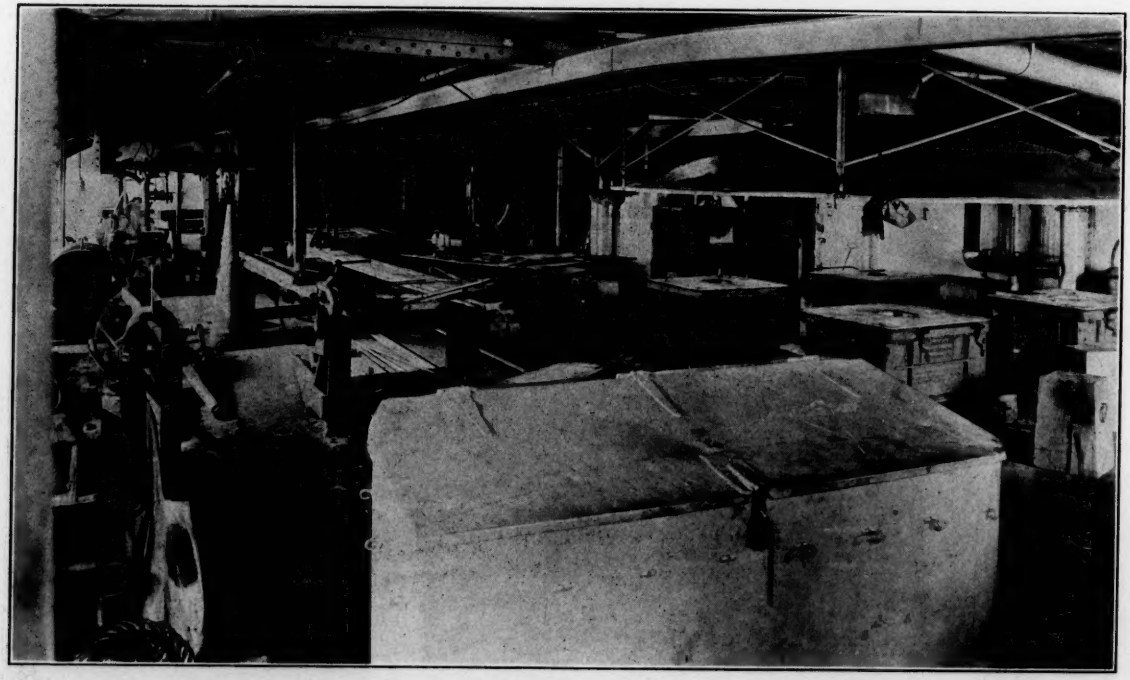
1—16-inch by 2-inch wet grinder; Kemp Mach. Co., Clark Motor, 2 H.P.

2—12-inch by 2-inch bench grinders; Hisey Wolf Co., H. W. Motor, 2 H.P.

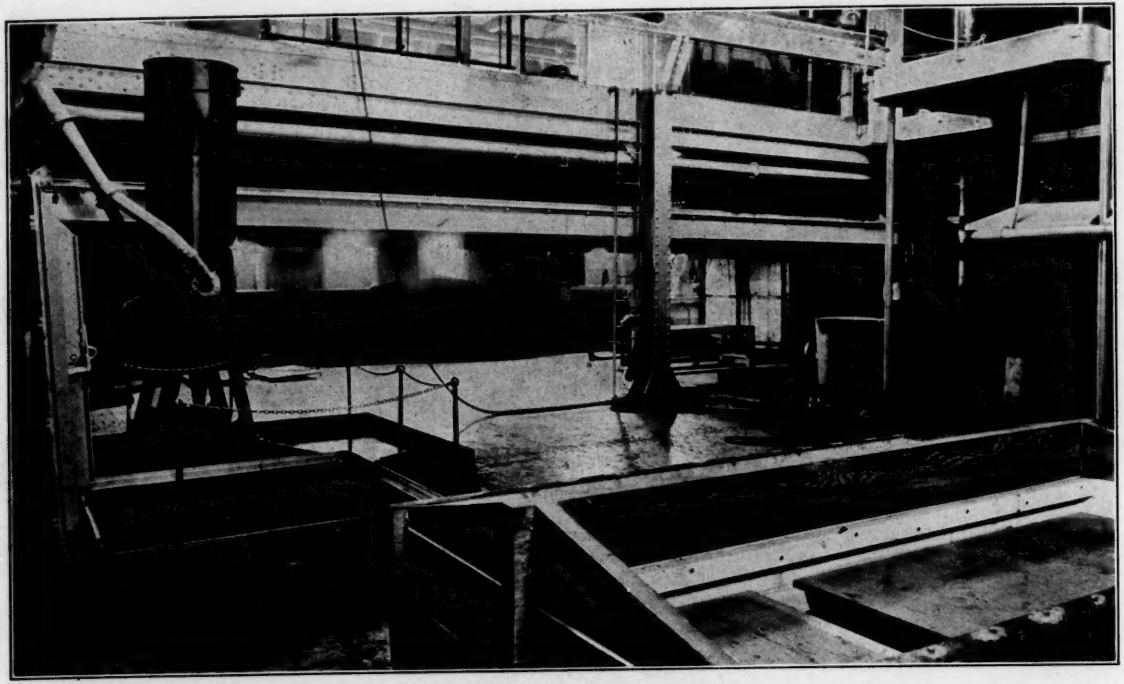
1—steam hammer; Buffalo Foundry & Machine Co.

1—universal plate machine, 48-inch throat capacity, ⅜-inch plate; Niles Bement Pond, Westinghouse Motor, 3 H.P.

1—200-ton capacity hydraulic forging press; Bethlehem Steel Co., steam power.



U. S. S. "MEDUSA". BLACKSMITH SHOP, LOOKING AFT.



U. S. S. "MEDUSA". FOUNDRY, LOOKING TO STARBOARD.

1—½-inch by 7½-inch throat hand punch; New Doty Mfg. Co.

1—30-inch throat single end punch, capacity ⅝-inch plate; Manning, Maxwell & Moore, G. E. Motor, 4 H.P.

1—bending roll, capacity ⅝-inch plate 72 inches wide; Niles Bement Pond, Westinghouse Motor, 10 H.P.

1—28-inch cold metal cut-off saw; Vandyck Churchill Co., Reliance Motor, 3 H.P.

1—hand-power shear, capacity ⅜-inch plate; Fairbanks Co.

1—30-inch throat single end shear; Manning, Maxwell & Moore, G. E. Motor, 4 H.P.

2—portable single-arc electric welders; Wilson Welder & Metals Co.

1—stationary 2-arc electric welders; Wilson Welder & Metals Co.

In addition to the above, there is supplied a complete outfit of hand tools and portable machine tools, such as drills, hammers and riveters.

Pneumatic and electric power leads, having outlets at the benches, are provided for the portable machine tools.

The combined shop is so equipped that the average run of fleet repair work can be expeditiously handled; and by the exercise of a little ingenuity, very large work, such as the fabrication of a smoke pipe or uptake, may be undertaken. The equipment is such that the work capable of being undertaken can be accomplished in the most modern and thorough manner, thus eliminating make-shift repair jobs.

SHEETMETAL AND PLATING SHOPS.

These connecting shops are located adjacent to the pipe shop, on the starboard side of the upper deck, between frames 90 and 105. A passage way, at frame 90 connects with the pipe shop, and the plate storeroom, located inboard, is readily accessible. An office, with a laying-out board, is located in the starboard forward corner.

SHEET METAL SHOP EQUIPMENT.

1—48-inch cornice brake, capacity, number 16 gauge iron; hand power; D. Nast Machine Co.
1—bench crimper and beader; Berger Bros. Co.
1—37-inch slip roll forming machine.
1—hand-power bench shear, capacity, 18 gauge; Peck, Stow, Wilcox.
1—37-inch square shear, capacity, 14 gauge; Fairbanks Co., Reliance Motor, 2 H.P.

PLATING SHOP EQUIPMENT.

1—14-inch by 2-inch pedestal type buffing machine; Jas. Clarke Elec. Co., motor same, 5 H.P.
1—potash steam kettle.
1—hot-water steam kettle.
1—scouring table.
1—tank for cold water.
1—sawdust box.
1—nickel plating tank.
1—copper plating tank.
1—acid-dip tank in acid room.
1—cold-water tank in acid room.
1—tank for cyanide solution.

In the plating shop there is a dry room and an acid room. For the plating tanks, which are electrically controlled, there is a separate switch board. The motor-generator is direct connected, 150 volts, 6 ampères; manufactured by the Connecticut Dynamo and Motor Co.

ELECTRICAL WORK SHOP.

The Electrical Work Shop is on the starboard side of the second deck, between frames 50 and 69, and has a floor space of 1200 square feet; of this area, a space of 580 square feet is taken up by equipment, leaving 620 square feet available for working space. This shop is practically a gallery, on the star-

board side, above the main machine shop and adjacent to the machine shop gallery, the latter being on the port side, and having the light work machines. This arrangement provides of ready access, via the main hatch, and a smaller hatch, to the main machine shop; and via athwartship passage ways to the machine shop gallery. All small work, beyond the capacity of the equipment of the electrical shop can be handled in the machine shop gallery, while the larger work, such as armatures, rotors, etc., can be handled in the main machine shop.

There are three work benches; two, 3 feet by 18 feet, work from one side only, and one, 4 feet by 17 feet, work from all sides.

EQUIPMENT.

1—Armature coil winder, 3 inches to 24 inches; Elec. Mfg. & Equip. Co.

1—Coil winding machine to handle coils 3⅝ feet long, 6 inches diameter; Universal Winding Co., Peerless Motor, ½ H.P.

1—2-ton Electric hoist, monorail system; Pawling & Harnischfleger, P. & H. Motor, 4 H.P.

1—12-inch bench drill; Kemp Mach. Co., Clark Motor, ⅓ H.P.

1—20-inch upright drill press; Fairbanks Co., Reliance Motor, 1 H.P.

1—10-inch by 1-inch double bench grinder; Hallidie Mach. Co., Clark Motor, 1 H.P.

1—16-inch by 10-foot engine lathe; Whitcomb Blaisdell Co., G. E. Motor, 3¾ H.P.

1—24-inch by 14-foot engine lathe; Fairbanks Co., Reliance Motor, 10 H.P.

1—8½-inch by 22-inch Cabinet bench lathe; Fairbanks Co., Reliance Motor, 1 H.P.

1—34-inch by 9-foot 6-inch Armature coil winding machine; Diehl Elec. Co. Motor, 2 H.P.

1—Electric armature baking oven, 9 feet 2 inches by 6 feet 2 inches by 6 feet 6 inches, Gehnrich Indirect Heat Oven Co.

1—Electric armature baking oven, 40 inches by 32 inches by 28 inches; Dispatch Manufacturing Co.

1—40-inch foot-power paper cutter; John Jacques and Son.

1—Armature coil spreader to be used in connection with armature winding lathe; Electric Service Supply Co.

1—Taping Machine; Elec. Service Supply Co., Robbins and Myers Motor, ⅛ H.P.

The coil taping machine is suited for taping armature coils only.

The coil winding machine is suitable for small coils only, such as are used in annunciators, fire control instruments, engine telegraphs, steering telegraphs and fireroom timing devices.

The 16-inch lathe will swing work up to 18 inches in diameter, and 6 feet long.

The 24-inch lathe will swing work up to 26 inches in diameter, and 6 feet long.

The universal armature machine is suited for winding armature coils, grinding and cutting commutators, and armature banding. This machine will swing armatures up to 30 inches in diameter, and 5 feet 6 inches long.

The armature coil forming machine will handle coils, where round wire is used, for armatures ranging in size from 1 to 50 K.W. The coils are first wound on the armature machine, and then placed in the coil forming machine for shaping so as to fit armature.

The small grinder is suited for small grinding, and the sharpening of tools.

The paper cutting shears are suitable for cutting the various insulations used in electrical work.

The available, working, floor space is great enough to permit 20 mechanics to work without undue interference. As

will be noted, there is a great amount of bench space, this with a view of making easy the rapid prosecution of small work. In the case of large work, it is probable that such work can better be handled in the main machine shop. This electrical shop, by making use of the machine shop facilities, is as well equipped to handle any electrical work as any navy yard, save in the instance of large propulsion generators and motors.

PIPE AND COPPER SHOP.

The Pipe and Copper Shop is located in a very convenient place, between frames 89 and 105, on the port side of the upper deck. It occupies a space 24 feet by 48 feet. A skylight and 18-inch ports furnish excellent ventilation and ample light.

EQUIPMENT.

1—24-inch, 3-jaw column chuck.
1—22½-inch sliding head drill press; Fairbanks Co., Reliance Motor, 2 H.P.
2—Portable marine, oil-burning furnaces; Hauck Manufacturing Co.
1—14 by 1½ combination wet and dry grinder; Manning, Maxwell, and Moore, Reliance Motor, 1 H.P.
1—12 by 2 bench grinder; Hisey Wolf Co., H. W. Motor, 2 H.P.
1—Pipe threading and cutting machine, 6-inch capacity; Landis Mach. Co., Westinghouse Motor, 7½ H.P.
1—35-ton hydraulic bending press; Camden Iron Works.
1—pump for press, discharge pressure 1800 pounds per square inch; Logeman Brass Co., Northenstrom Motor, 5 H.P.
1—pipe expanding machine, 6 inches; Lovekin Pipe Expanding and Flanging Co., Motor, 5 H.P.
1—1-ton hoist, monorail type, hand operated.

In addition to the above, the following hand tools and accessories are furnished:

2—Machinist bench vises, swivel jaw and base, each vise furnished with:

Three ⅝-inch flat chisels.
Three ⅜-inch cape chisels.
Three 18-inch 2nd cut flat files.
Three 18-inch 2nd cut round files.
One 1½-pound ball pean hammer.
One combined pipe vise, stationary jaw and swivel base.
One pipe vise hinged on open jaw, ⅛ inch to 4½ inches.
One copper smith's set of stakes with holder and bench plate.
One bearing babbitting outfit.
Two electric breast drills.
Four sets hand stocks and dies, ⅛-inch to 3-inch gas pipe.
Four sets hand taps and reamers, ⅛-inch to 3-inch gas pipe.
One set hand expanders, 1-inch to 7-inch pipe.
One set hand taps, U. S. Standard thread right hand with wrench.
Two sets of coppersmith's hand tools.
One set plumber's tools with portable furnace and torch.
Four sets pipefitter's tools.
Three oil-brazing torches.
Two oil-sweating torches.

For handling work, there is an overhead trolley extending the full length of the shop. One-ton chain hoists will be employed for handling heavy work, such as piping, kettles, etc.

Compressed air leads are run to convenient locations on the bulkheads and over the work benches; the latter are of large area and arranged to permit of the simultaneous prosecution of a large volume of work.

A combined tool and stock room, with metal shelving and bins, is located adjacent to the shop.

The shop equipment, all of the latest model, with the spacious layout, permits of threading, bending, and fitting screwed piping up to six inches; the fitting and expanding of tubing into flanges, up to eight inches, inside diameter; the handling

of all classes of copper work, such as brazing piping and flanges of all dimensions; the brazing of seams; bending of piping; manufacture of tanks, floats, etc.; babbitting; repairing of, and the lining of coffee urns and kettles; and the tinning and lead-lining of tubing and piping.

PRINTING SHOP.

The equipment of the printing shop consists of:

1 power printing press, Chandler and Price motor, ½ H.P.
1 hand paper cutter.
1 type filing case.

GYRO REPAIR SHOP AND LABORATORY.

These two small shops are located in the after end of the optical repair shop. The gyro compass repair room has a stand and electric panel installed for testing gyro compasses; in addition there is provided a complete set of hand tools.

In the testing laboratory, there is installed a small electric oven and a small still.

LOW PRESSURE EVAPORATORS.*

SUBMERGED COIL TYPE.

By Lieutenant Edward Ellsberg (CC), U.S.N., Member.
Planning and Drafting Superintendent,
Navy Yard, Boston.

It is the general policy of the Navy Department to equip all naval vessels with low pressure evaporating plants. New vessels are having such plants furnished as the original installation, and vessels to remain in commission are having their old plants converted as fast as funds and opportunity permit.

Low pressure evaporation is supplanting high pressure in our service for several reasons. The first and most important one is that it permits the use of exhaust steam which on most naval vessels is available without cost, and consequently the fuel consumption of the vessel is reduced.

A second reason is, that a low pressure plant (if properly designed and operated) will scale only to a slight degree in operation and as a result there will be no falling off in water production nor will the frequent scaling of tubes be required. The temperature corresponding to 10 pounds gauge is, with saturated steam, 240 degrees F. It has been found that hard scale, a sulphate deposit, ceases to form at 265 degrees F. From this temperature down to about 195 degrees F, a softer carbonate scale only, is formed. Consequently, if wet steam only, at a pressure not exceeding 10 pounds is used, sulphate scale is not formed. If the pressure is kept under 5 pounds, and proper submergence of tubes is obtained, scaling will be

* This article is based on the author's experience as Planning and Drafting Superintendent at the Navy Yard, Boston, Mass., in the design, installation, and operation of low pressure evaporators on the U. S. S. *Brazos, Denver, Utah,* and *Florida;* on personal observation of the operation of such plants on the U. S. S. *Raleigh, Wyoming,* and *Colorado;* and on reports of the operating experiences of the personnel on other vessels of the Navy having low pressure evaporator plants.

practically eliminated. If, however, live steam reduced through an orifice or a reducer is used, the steam will superheat and scale will result as in high pressure evaporators, unless special means are provided for abstracting the superheat before admitting the steam to the evaporators.

A third reason is that, by using a high vacuum, a large temperature range is obtained permitting operation in multiple effect, either double, triple, or quadruple, with consequent increase in economy. Multiplication of effects, however, does not correspondingly increase capacity.

At present the low pressure evaporation principle is being applied in two distinct and different manners on naval vessels. Low pressure advantages are inherent in low pressure and corresponding low temperature, and may be obtained by either method. One application involves the recirculation of the water in the evaporators in the form of rain over the tube nest, the water level in the evaporator being kept theoretically below the bottom row of tubes. This system, the film or flash type, is described at length in the JOURNAL OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS for May, 1923. This is the type installed at present on all new vessels of the Navy, being the first naval application of low pressure evaporators on a large scale.

In the other application, the tube nests in the evaporators are submerged about as formerly in the old high pressure evaporators, and no special circulation system is required. The simplicity of this system marks it as the next step in the development of low pressure plants and makes it the best method for realizing the benefits of low pressure evaporation on Naval vessels. Several applications of this design have been made at the Boston Navy Yard, with results that confirm this statement. A plant built on this system as actually installed and operated on the U. S. S. *Denver* will here be discussed and compared with Lillie type evaporators.

On the arrival of the U. S. S. *Denver* at the Navy Yard, Boston, in the fall of 1923, the Yard was directed to convert

the existing double effect high pressure plant to a double effect low pressure, non-recirculating plant. On examination of the *Denver's* existing equipment, it was found that both evaporator shells were seriously corroded and had been patched. It was decided not to use these evaporators again and they were removed and junked. There were on hand in the Yard two ex-*Utah* high pressure evaporators in good condition and these were selected for the *Denver*. For a distilling condenser, the existing port auxiliary condenser on the *Denver* was taken and relocated. Only one new item of equipment was supplied, this being a small reciprocating pump drawn from store for use as a brine overboard pump. A type plan of the layout is given in the sketches following. For convenience in tracing the piping, and for ease of comparison with similar sketches in the article on the Lillie type referred to above, the sketches are separated into

(1) Steam lines and first effect tube nest drain.
(2) Salt water piping.
(3) Vapor and fresh water piping.
(4) Air removal connections.

Steam for the plant is obtained from a 3½ inch connection to the auxiliary exhaust line. No connection to a live steam line is furnished in the evaporator room, this being to prevent the crew by any possibility wiredrawing the steam to a low pressure and consequently sending superheated low pressure steam to the first effect. The evil effects of using superheated steam, giving a temperature above 240 degrees F., have been noted above. On vessels of the class described here, sufficient exhaust steam is always available to operate the plant. On other vessels, if more steam is required, it may be obtained by bleeding live steam into the exhaust steam line as far away from the evaporators as possible, thus giving the steam a chance to lose its superheat before it arrives at the first effect coil.

A compound gauge and a 300 degree thermometer are installed on the line to the first effect in order that a check on the feed steam may be kept. The thermometer is considered more important than the gauge, especially for ships using live steam through a reducer.

A section of the tube nest is given in Figure 5. The steam passes through the tubes in the same manner as in the old high pressure operation. As the steam goes through the various passes, it is condensed and the condensate is taken out through a drain pipe at the bottom of the front head. A trap is fitted to maintain the water level just below the bottom row of tubes and thus prevent steam from blowing through.

This condensate, not being new water made, is returned for boiler use again, either to the hotwell, the auxiliary condenser, or the main condenser as shown in Figure 1. It is not fit for ship use owing to the presence of boiler compound or oil. The condensate comes out at a temperature nearly corresponding to the entering pressure, and its heat is partly made use of to heat the salt feed water. The heater used is of the same design and size as is used on the plants installed on the *Florida* and *Colorado,* with about nine square feet of surface, but this appears to be insufficient really to cool the condensate or to warm up the feed to any great extent. This heater with its by-pass is mounted below the drain regulator.

Two relief valves, one set at 12 pounds and one set at 15 pounds are fitted as shown to protect the coil. It may be noted that in this installation, as the coil was originally designed for high pressure operation, the protection is unnecessary as a safety device but is still required to prevent violent (though improbable) changes of temperature in the first effect coil due to high pressure.

Figure 2 shows the salt water piping. Circulating water is taken from the same sea chest which formerly supplied the port auxiliary condenser in its old location. A check valve is fitted just inside the stop valve. The circulating unit is part of the combined air, circulating pump, and condenser, formerly

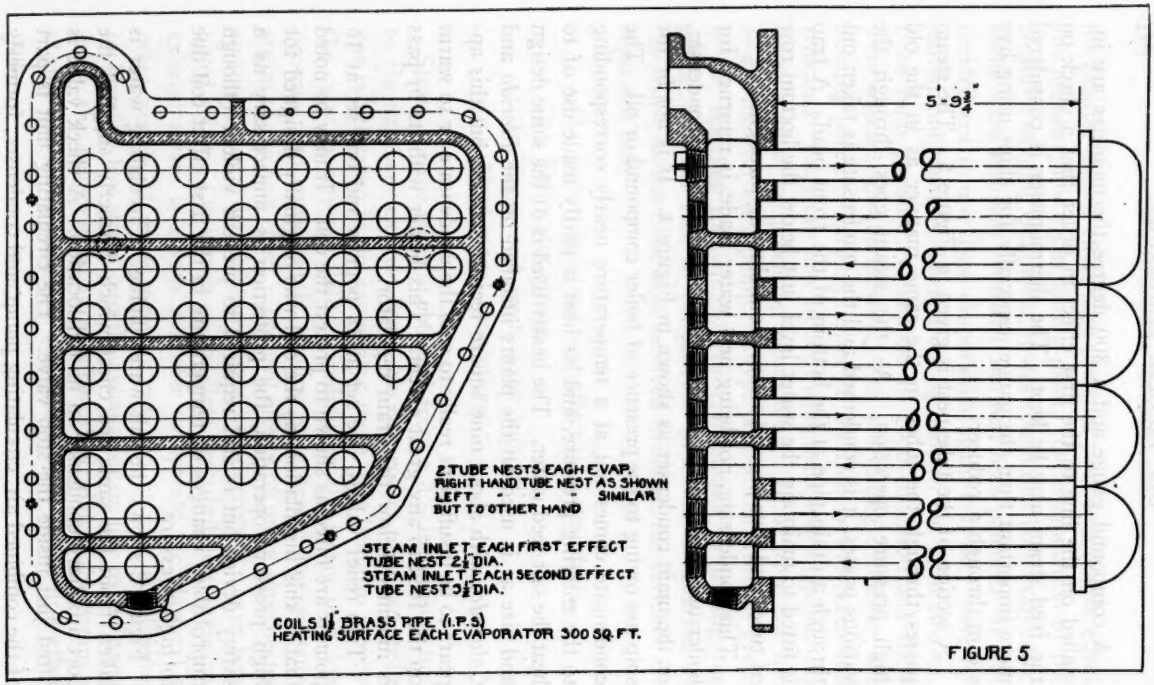
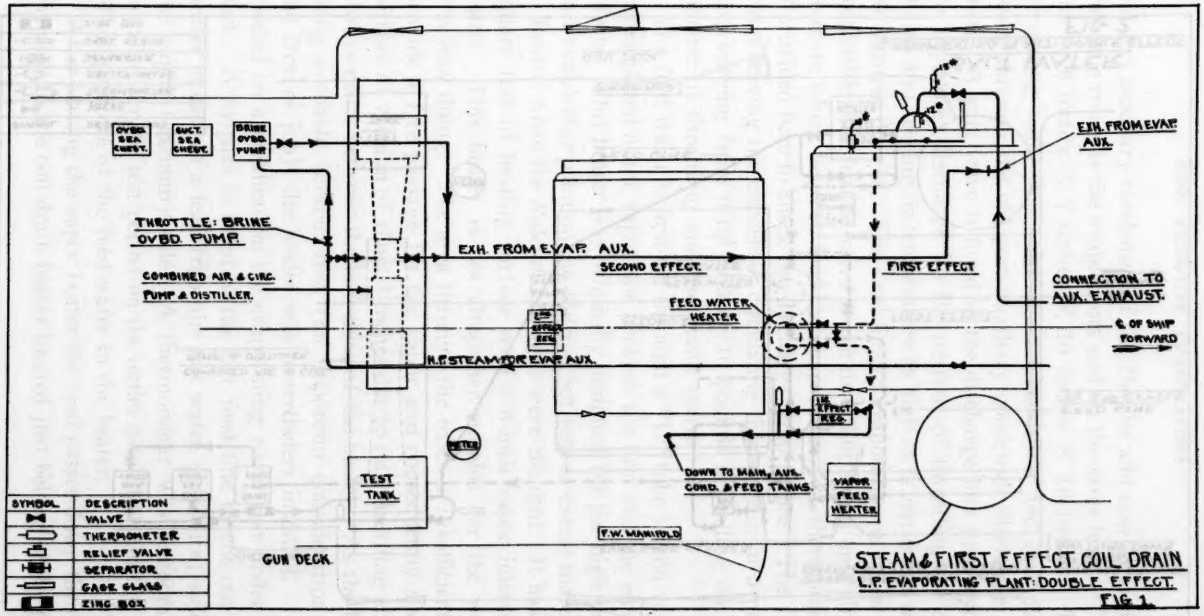

5'-9¾"
2 TUBE NESTS EACH EVAP.
RIGHT HAND TUBE NEST AS SHOWN
LEFT " " " SIMILAR
BUT TO OTHER HAND
STEAM INLET EACH FIRST EFFECT
TUBE NEST 2½ DIA.
STEAM INLET EACH SECOND EFFECT
TUBE NEST 3½ DIA.
COILS 1" BRASS PIPE (I.P.S.)
HEATING SURFACE EACH EVAPORATOR 300 SQ. FT.

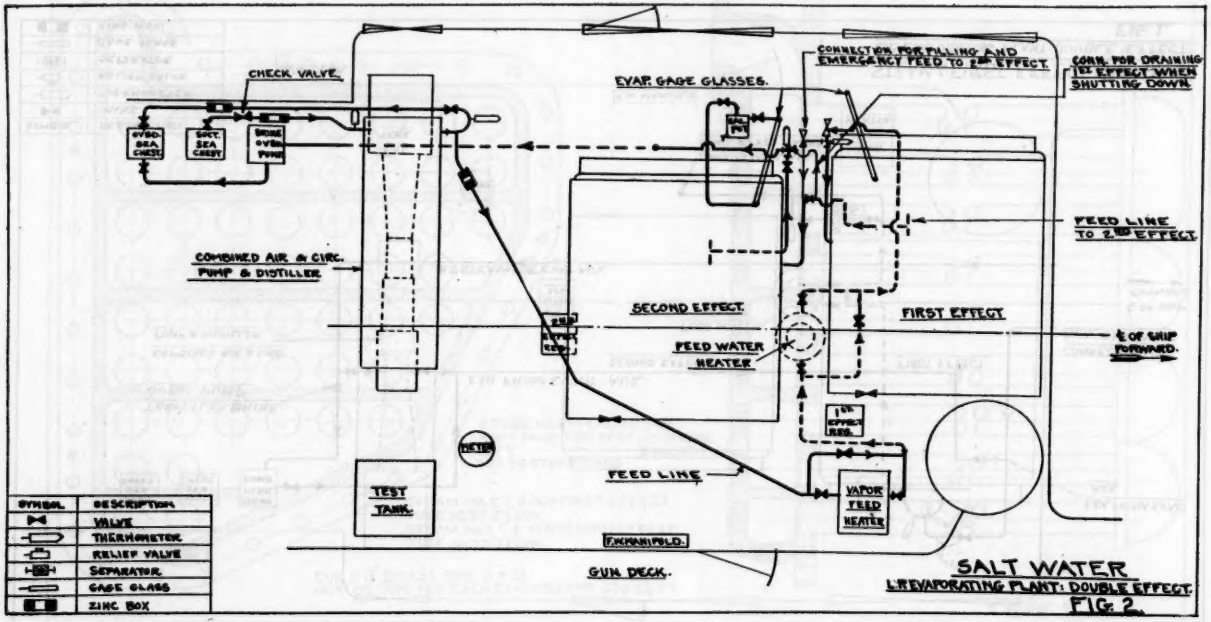
FIGURE 5



STEAM & FIRST EFFECT COIL DRAIN

L.P. EVAPORATING PLANT: DOUBLE EFFECT.

FIG. 1.



SALT WATER
L.P. EVAPORATING PLANT: DOUBLE EFFECT.
FIG. 2.

the port auxiliary condenser of the *Denver* and now located in the same room as the evaporators and on the same level. This unit is 6 inches × 7 inches × 10 inches × 10 inches. The circulating water passes through the condenser and goes overboard through the old port auxiliary condenser discharge sea chest. A gate valve is fitted in the discharge line just beyond the condenser discharge for the purpose of throttling the discharge and keeping its temperature as high as is consistent with the vacuum desired. The feed line to evaporators is taken off just inside this throttle valve as the throttling keeps up a slight pressure which helps to feed the evaporators. A thermometer is provided here to check the discharge temperature. The feed water leaving the condenser circulating discharge is at a pressure varying from 0 up to 5 or 10 pounds depending on the amount of throttling and the pump speed.

The feed water is first led through a "U" tube Dyson vapor heater placed in the vapor line between the first and the second effects. This heater was originally designed for the high pressure evaporator plant on the *Raleigh* but sent as excess material to Boston when the *Raleigh's* designs were changed. It has 30 square feet of heating surface with a 5-inch vapor inlet and outlet. This heater is not altogether suitable for the work it is now doing. The area through the tubes is insufficient to provide a free passage for the vapor and consequently a difference of vacuum of about 5 inches due to this throttling effect always exists between the two sides of the heater. As the best thing available without cost (an important consideration on the *Denver* job), the heater was nevertheless installed. It is located on a bulkhead in the evaporating room just under the deck. A by-pass is fitted in the salt feed line to cut out the heater in case of a leak from the salt water (pressure) side to the vapor (vacuum) side. A thermometer was temporarily installed for the test period on the outlet side to obtain the rise of temperature of the feed water in the heater.

After leaving the vapor heater the feed passes down through the deck to the coil drain heater located just below. A by-pass

is provided for the feed here as is the case of the vapor feed heater. After leaving the coil drain heater, the feed rises through the deck to the front of the first effect evaporator shell. Here a permanent thermometer is provided to show the final temperature of the feed as it enters the shell after passing through the two heaters.

All the feed enters the first effect shell through a hand controlled feed valve. No automatic feed regulator is provided nor has it been found desirable. The water is fed into the first shell until the level is nearly up to the top of the tube nest, thus practically submerging it. This is radically different from the Lillie type, where it is desired to keep the tubes entirely out of water. It is also somewhat different from high pressure practice, where to prevent excessive priming and salting of fresh water, the level is carried about halfway up the tube nest. This point will be more fully discussed later.

From the bottom of the first effect shell (formerly the bottom blow connection), the feed line to the second effect shell is taken off. This line has a gate valve in it to control the feed to No. 2, which is also the brine discharge from No. 1. A by-pass with a valve also connects this No. 2 feed line with the main feed to No. 1, but this connection is ordinarily closed except for the initial filling of the evaporators. It is seldom used in operation.

The water level in the second effect shell is kept up to the level of the top row of tubes, thus completely submerging them. This level is about 3 inches higher than in No. 1 effect and is also considerably higher than in high pressure practice.

From the bottom of the second effect shell (the former bottom blow connection) a brine discharge line is taken off which leads down to the brine overboard pump located below in the port engine room. This unit, a 3½ inches × 4¾ inches × 4 inches vertical reciprocating pump, draws the concentrated brine out of the second effect shell against the vacuum existing there and discharges it overboard. A salinometer pot is fitted to the second effect shell to test the brine concentration. The

brine overboard pump is run at such speed as to keep the concentration at the point desired, about 2.5/32. For ease in control, the steam line to the brine overboard pump is led through the evaporator room where a throttle valve is installed to permit regulation of the pump speed without leaving the evaporator room.

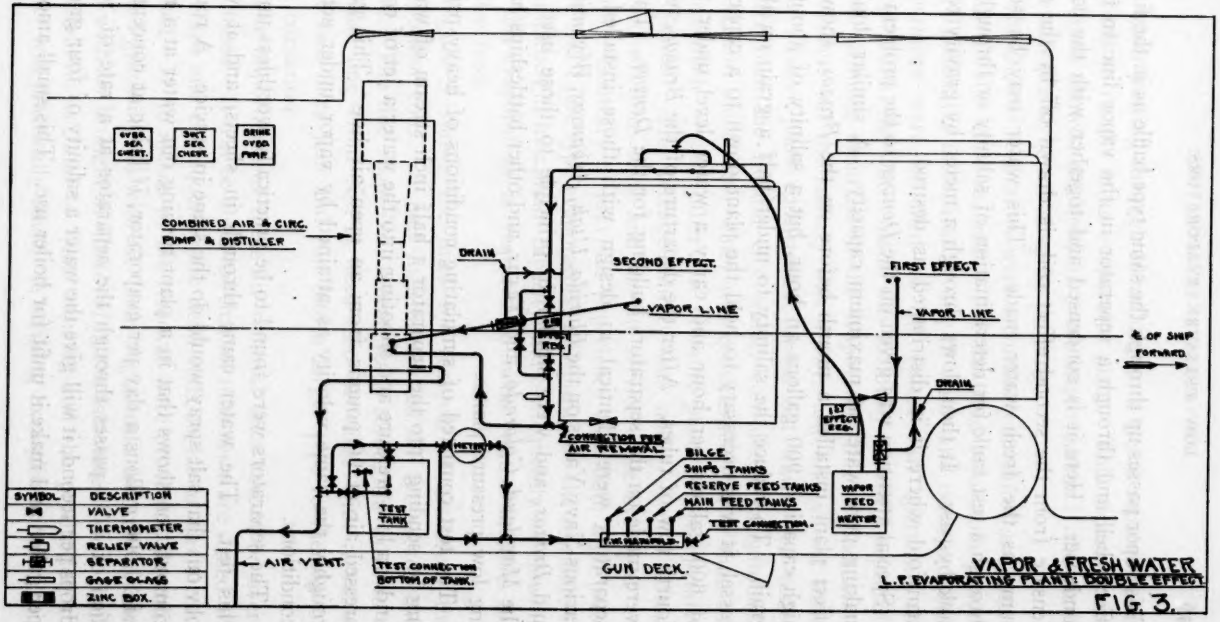
It will be noted that this is a series feed system. All feed is sent into the first effect, where part is evaporated. The remaining salt water at a somewhat higher brine concentration, is fed into the second shell where further evaporation takes place. The balance of the salt feed is all discharged from the second effect shell, thus leaving at the lowest possible temperature. No circulation pumps or intermediate feed pumps are used in this plant. The vacuum in the first shell is sufficient to pull its feed into it without a feed pump. The first shell is under a pressure 5 pounds higher than the second shell. Consequently, if a pipe of sufficient size, about 2 inches, is provided, the feed will flow from No. 1 to No. 2 shell by opening the valve in the line. This intermediate line on the *Denver* was only 1½ inches in diameter. As a result, at high capacity (over 3 pounds steam), it was not large enough to pass sufficient feed for No. 2 and auxiliary feed from the line to No. 1 shell was necessary.

Previous experience with both Lillie and submerged type coils had shown that the tubes or parts of tubes constantly washed or submerged, scaled only slowly. Lillie tubes only occasionally touched by water, scaled rapidly, and submerged tubes so high out of water as not to be constantly splashed, also gathered a coat of salt. In the submerged coil, therefore, a high water level is desirable to prevent scaling as well as to make use of all heating surface. However, here as in any boiler, a change in pressure conditions will cause priming, especially if the pressure in the shell falls or the pressure in the coil rises. To prevent solid masses of water from being thrown up into the vapor outlet pipe by priming or by rolling of the ship, a baffle plate of special design is installed in the

upper half of the shell. The baffle permits vapor and some entrained spray to pass out into the vapor pipe in the top of the shell. A water level covering the tubes was desirable also for evaporative efficiency in high pressure plants, but was not attempted in practice because of the priming and salting up of the distillate which resulted. It is believed that the *Denver* installation is the first in which this high level is successfully used. The operation of the baffle plate and the condition inside the evaporator as regards priming, can be observed through a 6-inch sight port located in the back head of the shell, just above the baffle plate.

Figure 3 shows the vapor and fresh water piping systems. The vapor made in the first effect passes through a separator located in the vapor line leading from the top of the shell. From the separator, the vapor passes through the Dyson heater previously mentioned (ex-*Raleigh*), where part of it is condensed in heating the feed. The remaining vapor passes into the second effect coil, to which the vapor condensed in the heater also drains. Here the remaining vapor condenses in the passes of the tube nest, giving up all its latent heat and some of its sensible heat. The condensate, now comprising all the vapor generated in the first effect shell, drains out the bottom of the second effect coils to a trap so adjusted as to maintain a water seal just below the bottom row of tubes. From the trap, the condensate is drawn by vacuum directly into the top of the condenser where the condensate is cooled off and drawn out by the air pump. No flash chamber is used. This method is possible as the condenser top is only about five feet higher than the bottom of the tube nest. Its advantage is that it obviates discharging hot water directly into the air pump suction with consequent liability to loss of vacuum, a trouble reported by numerous ships having flash chambers and condensate discharges from the flash chambers to the air pump suctions.

The latent heat given up in the second effect coil by the vapor from the first shell evaporates water in the second shell.



VAPOR & FRESH WATER
L.P. EVAPORATING PLANT: DOUBLE EFFECT.

FIG. 3.

This vapor passes up through the same type baffle as in the first effect shell and through a separator in the vapor line to the condenser. Here it is condensed and together with the condensate from the second effect coil, is drawn off by the air pump as the fresh water made. This water may be sent through a test tank for determination of salinity or through a tank by-pass. It then flows through a meter by gravity to a manifold where it is distributed as desired.

Special attention was given on the *Denver* to the problem of making pure water at maximum capacity. A similar double effect plant installed a month before on the *Brazos,* showed high capacity, 900 gallons an hour, but a salinity of about a grain. To reduce the salinity to under half a grain on that vessel, it was necessary to hold the plant down to a capacity of 600 gallons per hour and carry a water level under the fourth row of tubes. After the departure of the *Brazos,* tests were made on the separators building for the *Denver.* These separators were identical in design with those installed at various Navy Yards on the *Florida, Utah, Arkansas, Wyoming,* and *Brazos,* and were similar in principle to those used on the *Maryland, Colorado,* and *Texas,* and other battleships having low pressure plants.

The test consisted of simulating conditions of heavy priming by sending into the separator a half inch stream of water under a low pressure and shooting into the water a jet of compressed air at 90 pounds from an open air line. This gave roughly the same velocity as attained by vapor under actual conditions.

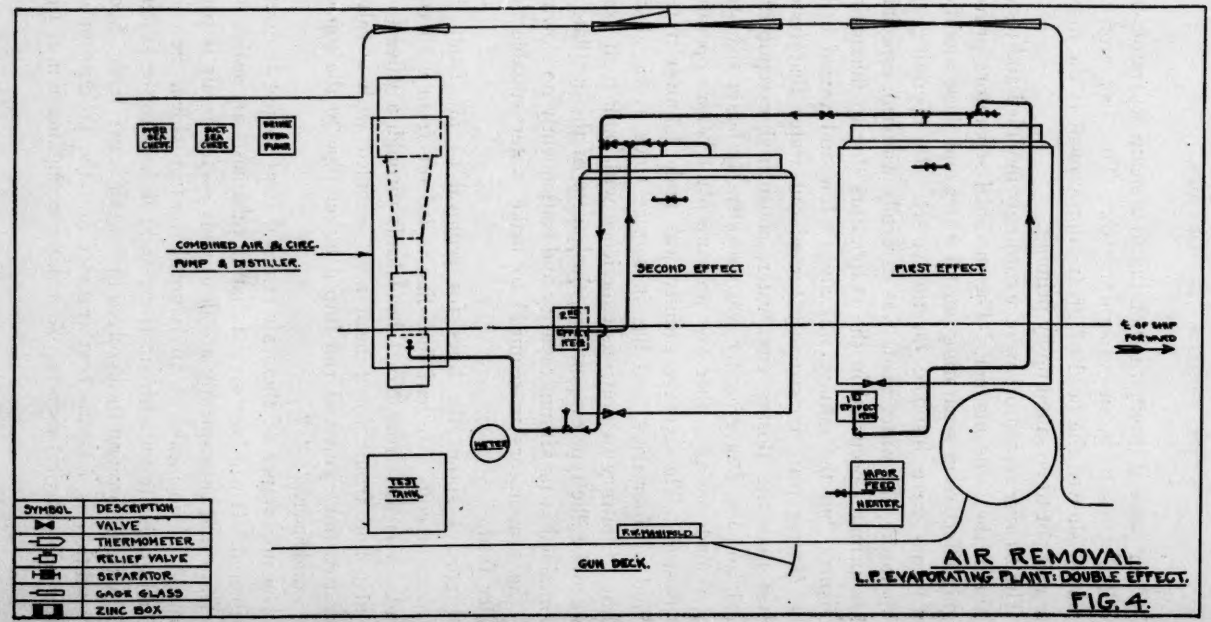
The separators were found to be practically worthless under this test. The water came through in sheets, and it was obvious that salt spray would do the same in service. A rough computation shows that in a plant turning out water at a rate of 10,000 gallons a day per evaporator, if brine at concentration of 2/32 passes through the separator at a rate of four drops per second, it will give the water a salinity of four grains per gallon and make it unfit for boiler use. This small amount

of water passing through is nothing to a steam separator, but is fatal to results in an evaporator plant. This separator experiment showed the need of great improvement if the distillate was not to be salted up by priming.

The *Denver* separators were accordingly modified and tested again in the same manner. The modified separators proved highly effective in separating out all water and these modified separators were installed on the vessel. In operating the evaporators, the water made was carefully watched, especially when priming occurred in the evaporators due to fluctuating pressures, but the salinity was always low and varied little. The *Denver* plant consistently turned out water that tested better than the Boston city water, considered exceptionally good, and the *Denver* water was considerably better than the water made by any other low pressure plant before operated at Boston. The average salinity was under .3 over a test period of four days, and has in service since averaged .28 grain. Contrary to previous experience with both high pressure and Lillie type evaporators, this purity of the distillate is maintained at maximum capacity and consequently no slowing of the evaporators is required to make water suitable for boiler feed.

Figure 4 shows the lines for removal of air from the evaporator coils. A half inch line is led off from each coil head. The line from No. 1 head leads through a valve to a similar line from No. 2 head also provided with a valve. The two lines join and run into a larger pipe to the top of the condenser.

The importance of these air removal lines cannot be overestimated. It will be observed that all tube nests are sealed off by traps and consequently are dead ends so far as air is concerned. If no means of air removal were provided, the coils would gradually fill with air from slight leaks into the system and with air brought in dissolved in the salt water feed. Such a condition is fatal to heat transfer and the production of water will practically cease. A striking exemplification of this



AIR REMOVAL
L.P. EVAPORATING PLANT: DOUBLE EFFECT.
FIG. 4.

11:00 A

Hour	Meter	Water per hour gals.	Salinity	Brine Con.	Steam Temp. Deg.F.	Pressures or Vacua #1 Coil	#1 shell vac.	#2 coil vac.	#2 shell vac.	Cond ser vac
11 am	6420		.3	2.5	205	5"	17		30.5	24.
Noon	7070	650	.3	3.25	214	1"	11	17.7	25	25.
1:30 pm	8460	Ave.	.3		204	5"	11	15	24	24.
2:30	9360	per	.2	4.5	220	1#	11	17.5	25	25.
3		hour								
4	10670	900	.2	3.5	220	1.5#	11	17	25	25
5	11620	950	.3	4.5		2.5#	8	15	25	25
6	12450	830	.3		220	3#	9	15	25	25
7	13350	900	.3	3	220	2.5#	10	18	25	25
8	14350	1000	.3	3.5	230	5.5#	8	15	24	24
9	15360	1010	.2	3.7	230	5#	8	15	25	25
10	16320	960	.2	4.	225	4#	6	15	23	24
11	17320	1000	.4	3.	228	5#	9	17	25	25
Mid.	18320	1000	.3	3.5	220	3#	9	17	25	25
1 am	19270	950	.5	2.75	224	3# x	6	15	24	26
2	20280	1010	.2	3.70	220	4#	9	17	25	26
3	21360	1080	.3	3.5	220	4#	9	16	25	25
4	22250	990	.3	2.70	220	4#	9	19	25	26
5	23350	1100	.4	2.5	222	4#	9	17	25	26
6	24350	1000	.2	2.5	222	5#	8	18	24	25
7	25220	870	.2	2.7	224	3#	6	15	24	25
8	26290	1070	.2	2.5	230	6#	9	18	25	25
9	27290	1000	.3	3.5	230	6#	10	19	25	26
10	28230	940	.3	4.5	230	6#	7	16	25	26
11	29300	1070	.2	4.0	220	4#	8	16	25	26

Production, water 24 hours 22880 gallons
Production, water per hour average 953 gallons
Salinity, average .284

Steam consumption for operation of all evaporating plant

U. S. S. DENVER
L. P. EVAPORATOR LOG SHEET
11:00 A. M. FRIDAY FEB. 1 TO 11:00 A.M. SATURDAY FEB. 2

Vacua		Temperatures - Degrees F							Exhaus
coil vac.	Condenser vac.	Injection	Overboard Disch.	Heater Disch.	Feed	Brine Disch.	#1 coil drain	#2 coil drain	cu. ft
24.5	24.8		66	119	168	137	147	144	
	25.6	33	68	161	180	138	175	160	
	24.8	33	70	162	176	144	190	166	
	26.5	34	76	161	176	146	198	166	
	26	34	64	152	154	98	198	154	
	25	34	80	144	148		186	156	
	26	34	80	142	148		187	158	
	26	34	78	145	150		198	144	
	24	34	92	168	168		180	154	
	26	32	82	160	180	148	180	180	302
	24	44	96	178	178	156	205	168	359
	25	34	84	140	152	150	198	164	420
	26	36	72	160	164	142	200	158	477.5
	26	32	104	198	148	150	156	162	534.5
	26	32	72	156	162	138	198	168	
	25	32	98	158	160	146	190	156	
	26	32	80	154	160	150	190	150	
	26	32	80	162	162	136	205	158	
	25	32	84	148	144	162	200	154	
	26	32	86	158	162	130	204	156	
	25	34	76	154	150	148	210	160	
	26	34	64	163	158	120		152	
	26	32	89	150	149	150	218	160	
	26	32	90	154	160	148	190	154	

g plant auxiliaries, 200 lbs. per hour, or 2400 lbs. of steam per day a

U. S. S. DENVER
L. P. EVAPORATOR LOG SHEET
11:00 A. M. FRIDAY FEB. 1 TO 11:00 A.M. SATURDAY FEB. 2

sures or vacua			Temperatures - Degrees F							Exhaust
#2 oil vac.	#2 shell vac.	Condenser vac.	Injection	Overboard Disch.	Heater Disch.	Feed	Brine Disch.	#1 coil drain	#2 coil drain	Me cu. ft.
	20.5	24.3		66	119	123	137	147	144	
.7	26	25.5	33	68	161	150	128	175	160	
	24	24.5	33	70	152	150	144	199	166	
.5	25	25.5	34	74	151	175	146	198	165	
	25	26	34	64	152	154	99	198	154	
	25	25	34	80	144	149		188	166	
	25	25	34	80	142	148		187	159	
	25	26	34	78	145	150		192	144	
	24	24	34	92	158	168		180	154	
	25	25	35	82	160	180	148	180	180	302
	23	24	34	96	172	178	156	205	168	359
	25	25	34	84	140	152	150	198	154	420
	25	26	35	72	160	164	142	200	168	477.5
	24	26	32	104	195	148	150	155	162	534.5
	25	26	32	72	156	162	128	192	168	
	25	25	32	92	158	160	146	190	155	
	25	26	32	60	154	160	150	190	150	
	25	26	32	60	162	168	126	205	158	
	24	25	32	84	148	144	162	200	154	
	24	25	32	85	158	162	130	204	156	
	25	25	34	76	154	150	148	210	160	
	25	26	34	64	163	158	120		152	
	26	26	32	89	150	149	150	218	160	
	25	26	32	80	154	150	140	190	154	

gallons
gallons

aporating plant auxiliaries, 200 lbs. per hour, or 2400 lbs. of steam per day =

Exhaust steam used

Meter Readings						
cu. ft.	cu.ft. per hour	Gal. per hour	True	Fresh water made	Ratio of water to steam	Hour
			Meter Constant = 1.37			11 am
						Noon
						1:30 pm
						2:30
						3
						4
						5
						6
						7
						8
302						9
359	57	427	585	960	1.64	10
420	61	457	626	1000	1.59	11
477.6	57.6	431	590	1000	1.69	Mid.
534.6	157.0	427	585	950.	1.64	1am
						2
	58.1	436	596.5	977	1.64	3
						4
		Average for 4 hours				5
						6
						7
						8
						9
						10
						11

day = 500 lbs. of coal per day (about).

fact was given on the first test of the Lillie quadruple plant installed on the *Utah*. Owing to an error in reading plans all air removal lines were blanked in the flanged joint next to the head by the mechanics who installed the plant; but from all outside appearances everything seemed correct. The plant was started up but in spite of the fact that the steam, the circulation, and the pressures were all normal, only a total of 800 gallons of water was made as the result of seven hours of operation;—hardly more than 100 gallons an hour. The error was discovered the next day, the blanks removed, and the plant immediately started to turn out water at a 1600 gallon an hour rate.

In operation, both air elimination valves are opened wide on starting up. After the plant has settled down, the first effect air valve is left slightly cracked and the second effect valve open about two turns.

As there are no evaporator circulating pumps in the *Denver* system, no gland sealing line is provided.

The evaporator plant on the *Denver*, when completely assembled, was filled with water and all lines subjected to a 10 pound pressure. About one working day was required to make up the leaks found. This test is considered important as, in operation, the greater part of the system is under vacuum and consequently leaks do not show up. The leakage of any amount of air into the system will adversely affect results.

The day after the pressure test, steam was turned on the plant and the pumps operated for purposes of adjustment. One day was spent in getting proper steam pump operating, the steam valve gear on the old condenser combined air and circulating pump requiring considerable adjustment before evenness of operation was secured.

The day following, Friday, February 1, 1924, the plant was operated as a whole for the first time. By 11 a. m., operation was fairly steady, and a 24 hour run was begun. The log sheet for this day is given on accompanying folder. The only difficulty encountered on trial was in getting sufficient exhaust

steam. It will be noted that a vacuum existed in the first coil for several hours. The ship being tied to the dock, at first had very few auxiliaries in operation. By afternoon more auxiliaries were started and a low back pressure built up in the auxiliary exhaust line. No auxiliary condenser was run during this test, all the exhaust steam going to the first effect evaporator. The pressure fluctuated continuously after the first two hours, the pressures put down being the maxima for each hour. The average pressure throughout the 24 hours was about 3 pounds. This unevenness of pressure at times caused violent priming in No. 1 shell, but had little affect on No. 2 shell.

The total production of water for the 24 hours was 22,880 gallons, giving an hourly average of 953 gallons, with an average salinity of .284 grain per gallon.

The best hour produced 1,100 gallons of .4 grain water with a maximum steam pressure of 4 pounds and a brine discharge concentration of 2.5/32. The worst hour was the first, which produced 650 gallons of .3 grain water with the steam under a 5 inch vacuum and a brine concentration of 3.25/32.

The following Monday, February 4, operation was resumed and maintained continuously for three days. The ship's regular evaporator room force took charge of operation. For their first 24 hours of operation they turned out 23,000 gallons of water, having an average salinity of .3, using exhaust steam under an average pressure of 2 pounds at the first effect coil, the maximum pressure for that day being 4 pounds, and the minimum 0 pound. The brine discharge concentration averaged about 3/32, running up occasionally to 3.5/32.

At 2 a. m., Wednesday, February 6, the plant was shut down, having run for 62 hours. In this time it produced 58,990 gallons of water on an hourly average of 952 gallons. The production when the plant stopped showed no signs of falling off due to scaling or other causes.

It was desired, previous to the departure of the vessel, to draw a coil from each shell for examination as to scaling. As

much running as possible was, of course, desirable to afford ample opportunity for scale to form but as the vessel's sailing date was set for February 7, the examination could not be delayed beyond February 6. On that day, then, the plant was shut down in the early morning for examination and the right hand coil in each evaporator drawn out of its shell.

As had been anticipated, no scale had formed on any tube nest. The coils, which were the ex-*Utah* high pressure coils had been scaled by Yard workmen but it was not possible to get at all the old hard scale adhering to the tubes when scaling these coils for use on the *Denver*. The tube nests had been put in the shells with this scale remaining. A considerable quantity of this old scale was now found to have cracked off and lay in the bottom of each shell. No new scale of any kind had formed.

It was realized that a period of operation of 62 hours was not a long enough time to form an opinion as to the amount of time it might take to scale up, but as no scale began to form after 62 hours, it seemed unlikely that scaling to any extent was likely after longer service. The *Denver* has since reported that after seven weeks of operation at an average capacity of over 20,000 gallons, a 1/16 inch coat of scale was found on the tubes of No. 1 coil; the tubes of No. 2 coil were found clean. This accords with theory, as the temperature in No. 1 coil is about 220 degrees F., which is higher than the critical point for formation of carbonate scale.

A study will now be undertaken of the efficiency of this plant. A temporary meter was installed to measure the feed steam used. This meter was calibrated in place.

For the four-hour period from 9 p. m. to 1 a. m., the average conditions as shown by the log are:

Water, gallons	977
Steam used, gallons	597
Brine concentration	3.5
Steam pressure, pounds	3

No. 1 shell, inches	9
No. 2 coil, inches	15
No. 2 shell, inches	24
Vacuum, inches	26
Over discharge, degrees F	80
Heater discharge, degrees F	160
Feed temperature, degrees F	166

Using the steam pressure above, the same brine concentration at discharge and the same heating effects of the heaters, the theoretical performance of the plant follows:

Assuming 1.69 pounds of water per pound of steam used, there will be discharged .677 pound overboard at concentration of 3.5/32. This gives a total feed of 2.367 pounds per pound of steam.

In No. 1 shell this is heated from 166 degrees to 194 degrees requiring $2.367(194-166)=2.367\times28$	=	66.2	B.T.U.
The pound of steam has a latent heat of		959	B.T.U.
Leaving		892.8	B.T.U.
There will be evaporated in No. 1 shell $\frac{892.8}{978}$	=	.914	lbs.
Hence the feed to No. 2 will be $2.367-.914$		1.453	lbs.
In the heater 2.367 pounds are raised from 80 degrees to 160 degrees F. requiring 2.367×80	=	189.5	B.T.U.
There is condensed here $\frac{189.5}{978}$	=	.193	lbs.
Leaving $.914-.193=.721$ pounds to go to No. 2			

In No. 2 shell the feed gives up

$1.453 \times (194-141) = 77$ B.T.U.

Latent heat is $.721 \times 978 = 707$

Giving for evaporation in No. 2 shell 784 B.T.U.

There is evaporated

$$\frac{784}{1012} = .776 \text{ lbs.}$$

Total evaporation $.914+.776 = 1.690$ lbs.

Discharged .677 pounds overboard at 3.5/32 concentration.

It appears from the above that if there were no losses, under conditions above, 1.69 pounds of water per pound of steam should be made. Actually, the plant turned out 1.64 pounds of water per pound of steam, giving it an efficiency of

$$\frac{1.64}{1.69} = 97 \text{ per cent.}$$

The low pressure plant as installed on the *Denver* is simple in operation. But two steam driven auxiliaries require to be run, and the feed valves to the evaporators require little adjustment to maintain a steady level. The complications of circulating pumps are altogether absent. No one who has ever run a Lillie plant would expect a green crew to pick up its operation in 24 hours, so that after that period they could drive it steadily themselves and get maximum production hour after hour. Four non-rated men and a chief petty officer took charge of the *Denver* plant after one day's operation by the Yard force, and thereafter without supervision exceeded even the production obtained by the Yard.

The installation, after three weeks of service operation, reached its best day's production with a daily rate of 28,000 gallons of .29 grain water at a steam pressure of four pounds. The same double effect plant on another vessel capable of supplying exhaust steam at a steady pressure of 5 pounds would undoubtedly produce an average of 25,000 gallons a day.

As the standard type for future Navy installations, the submerged type evaporating plant may be compared with the film type under five heads:

(1) Cost of installation.
(2) Cost of operation.
(3) Ease and certainty of operation.
(4) Thermal efficiency.
(5) Capacity.

For the purpose of this comparison, two installations made at the Boston Navy Yard will be used as types. The film type will be represented by a quadruple plant as installed on the *Utah;* the submerged type by a quadruple plant based on the *Denver* double effect plant. The comparison is rendered more apt as the *Denver* evaporators are the ex-*Utah* high pressure evaporators, with the same shell dimensions as the present *Utah* low pressure evaporators. These shells are all about 6 feet in diameter and 6 feet long. The *Denver* coils have a heating surface of 300 square feet per evaporator; the *Utah* film type coils have a heating surface of 400 square feet per evaporator.

The items required for each plant (duplications installed on the *Utah* not included):—

	Lillie	Submerged
Air pump	1 }	1 combined air
Circulating pump	1 }	and circulating
Brine overboard pump	1	1
Brine circulating pumps	4	0
Total	7	2

(1)—Cost of installation.

(*a*) The submerged type evaporator is essentially a simple system and dispenses with circulating pumps, circulating pump motors, suction piping and discharge piping for the circu-

lating system, sump tanks, sump strainers, automatic feed regulators, feed strainer baskets, distribution plates, and the special film type coils, all of which are part of the film type evaporating plant. Based on the prices paid for the pumps and coils supplied on Bureau contract for the *Utah* film type plant, and on the cost of building at the Yard and installing on the *Utah* the other accessories required, it appears that a quadruple film type plant will cost 20 per cent more than a submerged quadruple plant of the same size. In the ordinary case, this will amount to about $15,000.

(2)—Cost of operation.

(*a*) The largest difference in operating cost comes in the operation of the auxiliaries. As the submerged type plant runs without brine circulating pumps and with a minimum number of other auxiliaries, the fuel consumption chargeable to the plant is much reduced. The engineer officer of the *Utah* reports that to operate the auxiliaries required for his plant, running either as two double effects or one quadruple effect, takes three tons of coal a day, for which he gets about 30,000 gallons of water, or about 10,000 gallons of water per ton of coal. The *Denver* plant runs on about one-fifth of a ton of coal per day for auxiliaries, for which it produces over 20,000 gallons of water, or about 100,000 gallons per ton of coal.

(*b*) On the personnel side, at least two men per watch are required to tend the feed and the circulation on a quadruple Lillie plant, two evaporators being more than sufficient to keep one man engaged trying to maintain a steady water level in them. With the submerged type, the absence of circulation and the large volume of water in each shell, make water tending simple. One man can easily look after all four evaporators and their auxiliaries. With limited engineering personnel, this side of the cost of operation is of importance.

(3)—Ease and certainty of operation.

Any person who has been associated with the operation of a Lillie type plant realizes the difficulties involved in the

circulation feature. Suction troubles were, and are, prominent and chronic problems. Getting a circulation is often difficult. On most ships, with the pumps located in the evaporating room with heads of three feet or less, the circulation problem will always be acute. Since in each evaporator, the water is practically at the boiling point, it is always likely to flash in the pump and spoil the suction. In addition, slight air leaks along the packing of the pump shafts produce the same result. To offset this, gland sealing and all sorts of packing combinations have been tried out but the problem is still a live one on most ships. Tight packing wears out the shaft; loose packing spoils the suction. A solution used on the *Utah* and *Florida* was to place the pumps in the engine room 20 feet below the evaporators, with great improvement in results, but this is a solution not applicable to all vessels owing to lack of space or lack of height below the evaporators. It involves also considerable expense for the long pipe leads required.

Assuming that circulation is obtained, even distribution over the spray plate is not obtainable owing to variable trim, and clogging of distribution plates and baskets. Some tubes get little or no rain. Scale forms, cracks off, and clogs feed strainers, which on the *Utah* require to be shifted and cleaned out every watch.

The water level must be closely watched. Low water in any shell causes the circulation in that shell to cease and upsets the operation of all four units. High water causes violent priming, high salinity, and practically stops evaporation in that shell, also upsetting the plant operation.

Automatic feed regulators, provided with all Lillie plants, have proved unreliable as they soon clog with scale. Their use has been discontinued on many ships, as reported on the *Maryland*. Hand feed requires close watching as the feed pressure is usually supplied by the brine circulating pumps and pressure may exist or not, depending on how well the circulating pump is operating at the moment. A given opening of the feed valve may at one time give no feed at all, and a few

minutes later flood the shell before the man on watch can catch it.

High water, low water, poor circulation in any shell, and the production of the entire plant drops very low or ceases. It takes a good crew to strike a balance again and resume normal production in less than half an hour.

Scaling tubes is not eliminated. It is inherent in the rain feature that some scale will form, owing to intermittent contact of rain with tubes. Circulation troubles aggravate this feature. The *Maryland,* operating with 5 pounds or less, reports the necessity of scaling first effect coils weekly, and then circulating dilute acid through all three effects for about eight hours. In addition, a daily shut down for an hour is required to open and clean sumps and strainers. On the *Utah,* there is a weekly shut down for cleaning sumps, strainers, and spray plates. Every other week the first effect pumps are taken apart and scaled, and the brine circulating lines are opened up at the same time.

The staggered tubes and close spacing necessary in film type coils to obtain distribution of the rain over the tubes, makes it practically impossible to scale any but the outer tubes, leaving the great mass of tubes in the inside of the coil to accumulate scale which can be removed only chemically, if at all.

For the *Denver* submerged type plant, the simplicity of its set-up insures both ease and certainty of operation. Circulation, with all its troubles, is gone. There are no brine circulating pumps to lose suction, or leak gland sealing water over the decks; no brine circulating pipes with additional chances of heat losses and air leakage; no spray plates; no feed strainer baskets to shift and clean; and no sumps to keep cleared out.

There is a large volume of water in each shell. Variations in water level cause no annoyance. The feed pressures, being the difference in pressures between shells, are practically constant and the hand feed valves may soon be set at the opening required and then need little attention. The tubes, submerged at all times, are favorably situated to resist all scaling due to

mechanical deposition. The *Denver* reports that after seven weeks the second effect coils showed no scale at all, and the first effect coils showed only a coat 1/16 inch thick. As the *Denver* coils are designed for accessibility for scaling, it was a simple matter to knock this coat off. The *Denver's* experience shows that only once in six weeks is even a light scaling desirable. Consequently, the labor of frequent scaling is avoided and the capacity remains high over a long period. Shut down for circulating dilute acid or cleaning sumps is unnecessary. Only one pump, the brine overboard discharge pump, is required to work under a vacuum instead of five as in the Lillie system. This pump requires only a two-inch lead from the fourth effect evaporator. No trouble or expense will be found in locating this one pump sufficiently below the last effect shell to insure its maintaining a suction. This unit, a small reciprocating pump on the *Denver,* was placed in the engine room below the evaporators and never once lost its suction in four days of test operation. No gland sealing line or priming connection is required with it.

That the *Denver* submerged type is practically fool-proof in operation was shown when men not previously acquainted with low pressure evaporators took charge of watches after a few hours observation and ran the plant at maximum capacity without difficulty. The converse has many times been noted on Lillie plants where experienced men have had great difficulty in obtaining circulation, and in maintaining it.

(4) Thermal efficiency.

Both a Lillie plant and a submerged coil plant will have the same theoretical thermal efficiency and, if operating under the same conditions of steam and vacuum, will theoretically produce the same amount of water per pound of steam. In actual practice, the submerged coil type has a higher thermal efficiency which, though small, is appreciable and demonstrable under two heads.

(*a*) The condensed steam in either type is at first at the temperature corresponding to its pressure. In the Lillie type

this condensate in the fourth effect immediately drains out and is lost in the condenser. In the first effect it drains out and is usually lost, owing to small heating area in the drain cooler. In either first or last effect, it is of no use in the coils, as these coils are only intermittently in contact with spray.

In the submerged type, the condensate must make several passes through tubes always submerged in brine at a much lower temperature and consequently the condensate in the first and last effects parts with a considerable amount of its sensible heat before it is discharged from the tube nest. This process represents a heat gain of approximately 2 per cent for the submerged coil evaporators.

(*b*) In the Lillie type plant there is only a small amount of water in each evaporator. This water is continuously and rapidly circulated. The circulation pump and the suction and discharge piping are required to be external to the evaporator, and are located below the evaporators in relatively cool spaces. The pumps cannot be lagged. The pipe joints and the pipes themselves cannot always be lagged. The brine must, of necessity, experience a continuous heat loss in its circulation system. This loss cannot easily be measured, but it is obviously always present. This heat loss, the submerged type coils, through entire absence of circulation pumps and piping, is spared.

These two points represent a gain in thermal efficiency for the submerged coil type which may amount roughly to as much as 5 per cent, and some gain is always present in the submerged coil design.

A direct comparison of the thermal efficiency cannot be made between the *Utah* and the *Denver* as no records exist for the *Utah*. This comparison can, however, be made with the double effect Lillie plant on the *Raleigh*, tested at Boston within two weeks of the *Denver* tests.

The same meter was used in the coil drain lines from the first effects on each vessel. This meter, being used for hot water, was calibrated in place on each ship by measuring the

water in drums and comparing the quantities measured with the meter. The results were as follows:

Ship	Type	Pressure	Pounds water made per pound steam used
Raleigh	Lillie double	0 pound wet steam	1.56
Raleigh	Lillie double	5 pounds wet steam	1.50
Denver	Submerged double	3 pounds wet steam	1.64

(5) Capacity.

The capacity of an evaporator under fixed conditions of temperature and pressure, is a function of—(*a*) the effective heating surface; (*b*) the relative velocity of the steam in the tubes and the water in the shell; (*c*) the condition of the tube surfaces as regards scale; (*d*) the purity of the water desired.

(*a*) The effective heating surface first depends on the area provided by the evaporator tubes. This feature is fixed by the construction of the tube nest. All of this surface is, however, not necessarily effective. In high pressure evaporators probably half of it was never submerged and consequently was not in contact with the brine. In Lillie tube nests, observations based on five different installations showed that about one-quarter of the surface was ordinarily not touched at all by the spray and that the remaining three-quarters was not constantly surrounded by a water film. It is unlikely that more than half the heating surface in a Lillie tube nest can be considered as constantly effective. In the *Denver* installation, conditions are such that the water level can be brought up to the under side of the top row, submerging all the tubes below and constantly washing the top row by the water in ebullition. Here the entire heating surface is made effective for transferring heat.

(*b*) The rate of heat transfer is dependent on the relative velocity of the water and the steam. In Lillie tube nests the steam in the tubes has but slight velocity. It enters all tubes

at once from the front head. There is no flow of steam into a tube except as necessary to replace the steam condensed in that tube. Consequently the steam contributes nothing to the relative velocity. What relative velocity does exist is supplied by the spray dripping by gravity over the tubes at a velocity never exceeding 16 feet per second.

In the submerged coil tube nest, all the steam enters at the top and passes back and forth through the tubes till it all drains out at the bottom row as water. It will be observed that this keeps up a continuous flow of the steam through the tubes, at a velocity around 100 feet per second. In addition the continuous boiling of the brine keeps it in rapid circulation adding to the relative velocity difference between the two sides of the tubes.

(*c*) The rapidity of heat transfer is vitally affected by the cleanliness of the tubes as regards scale. Even a thin coat radically cuts down the transmission and consequently the capacity. In a high pressure evaporator this scale forms quickly. In a low pressure evaporator it will not form by chemical action if the temperature is below 195 degrees, but it does form by mechanical deposition if a tube is only occasionally washed with water. In Lillie evaporators irregular circulation and the spray feature always, more or less, give rise to this condition, causing formation of scale and loss of capacity. In the submerged coil design under discussion, the constant contact of low temperature water with the tube prevents the formation of scale mechanically and retards its formation chemically.

(*d*) The purity desired in the water made is an important limiting feature in most evaporators, as forcing the evaporators causes violent priming with salting of the distillate. This feature in high pressure evaporators at maximum capacity compelled a low water level or high salinity resulted. In Lillie evaporators if the circulation is accelerated the splash from the spray plate or from the sides of the nest, fills the vapor space with spray and finely divided mist resulting in high

salinity. Consequently, the large freeing surface present in the Lillie tube nest is of no great benefit in getting high capacity with low salinity. So far as can be judged, it is for this feature, the large freeing surface, that the Lillie type is chiefly used. It does not appear, however, that sufficient benefit is obtained in practice to outweigh the disadvantages inherent in the circulation feature.

The *Denver* submerged coil evaporator is so designed that the special baffle plate and separator before referred to, take care of the purity of the water under all conditions. The priming of the evaporators due to external influences resulting in changes in the feed steam pressure are of no great importance. This vessel has on test and in service consistently made water at maximum capacity of a standard of purity under .3 of a grain per gallon.

Having considered certain factors governing capacity, comparative results as obtained on various ships of the Navy may be cited. A direct comparison of capacity between the whole *Utah* plant and the *Denver* plant is impossible, as one is a quadruple and the other a double effect. However, the *Utah* plant is also piped for operation in double effect. The *Utah* reports, using feed heaters, an average output of water suitable for boilers, .5 grain water, of 800 gallons an hour. The *Florida* (similar to the *Utah*) now operates her plant regularly as two double effects. Under these conditions the vessel reports an hourly rate of 950 gallons per double effect with steam at about eight pounds, and an hourly rate of 700 gallons with steam at about three pounds. On both these ships, double effect operation uses the feed steam in one evaporator head (the normal third effect evaporator) to heat the feed water in addition to the usual heater installed between the first and second effects. This procedure on these ships increases the output over that of normal double effect, but also increases the amount of exhaust steam used.

The *Maryland* reports that one triple effect Lillie plant, with feed heaters, turns out 500 gallons of one grain water

an hour at one pound pressure, and at four pounds turns out 900 gallons. After one week's operation, the capacity for the triple effect drops, due to scale, to 500 gallons at five pounds pressure, after which the tubes are scaled.

The *Colorado* has two sets of four evaporators, each set piped in quadruple effect. This vessel turns out 850 gallons an hour with each quadruple set, the water having a varying salinity of from .6 to 1.0 grain per gallon. The steam pressure used is four pounds. A higher pressure very quickly scales up the evaporators and cuts the capacity.

A more direct comparison with a double effect Lillie evaporating plant is given by the U. S. S. *Raleigh*. This vessel was delivered at Boston the day preceeding the *Denver's* departure, and the *Raleigh* test was carried out practically under the same conditions as on the *Denver*. The *Raleigh* plant, using feed heating produced 850 gallons of .4 grain water with wet steam at five pounds pressure. At zero pressure with wet steam it produced 650 gallons per hour.*

Against these results may be set the *Denver* plant. Over the test period of four days the average output was 950 gallons an hour of .3 grain water with exhaust steam at 3 pounds. The ship could not provide a back pressure sufficient to go above 3 pounds. After seven weeks away from the Yard, the *Denver* reported an average output for that period of 949 gallons an hour with steam at 3.2 pounds, and with a salinity of .29 grains, showing results in service even better than on test.

These results are tabulated on page 464 for comparison.

The following is quoted from a report to the Bureau of Engineering made by the Commanding Officer of the *Denver* three months after the installation:—

"Since the new distilling plant has been in operation, a sufficient supply of fresh water has been obtained with practically

*NOTE: It was noted on this *Raleigh* test that if live steam reduced through an orifice was used, the steam became superheated. A test thermometer installed in the steam line showed that at 5 pounds, the temperature rose as high as 280 degrees F. As the builder's trials were carried on with such steam, the results are unreliable as showing plant capacity. The superheated steam gives a temperature range in the first effect even greater than that for a high pressure evaporator and much greater than for normal operation. Consequently, the plant shows a capacity much above that possible with wet steam. Scaling, of course, will shortly result and cut the output radically.

Ship	Type	Effects	Steam	Water gals. per hour	Sal. Grs. per gallon	Water per Pound of Steam	Remarks
			Pounds				
Utah	Lillie	Double	About 8	800	.5	Not measured	Feed steam used in one feed heater
Utah	Lillie	Double	3 to 5	605	.5	Not measured	"
Florida	Lillie	Double	About 8	950	Unknown	Not measured	"
Florida	Lillie	Double	About 3	700	Unknown	Not measured	"
Maryland	Lillie	Triple	About 1	400	1.0	Unknown	Just scaled
Maryland	Lillie	Triple	About 4	900	1.0	Unknown	Just scaled
Maryland	Lillie	Triple	About 5	500	1.0	Unknown	After 1 week
Colorado	Lillie	Quadruple	4	850	.8	Not measured	Service results
Raleigh	Lillie	Double	0	650	Varying	1.56	Yard test
Raleigh	Lillie	Double	5	850	.5	1.50	Yard test
Denver	Submerged	Double	3.0	950	.3	1.64	Yard test
Denver	Submerged	Double	3.2	949	.29	Not measured	7 weeks average
Denver	Submerged	Double	3.5	850	.27	Not measured	Over 3 months period*

*Plant scaled once in this interval.

no night watches. The production of fresh water is five (5) times that of the old plant. The operators have had few mishaps due to inexperience. The units of the plant are all in excellent condition and no difficulty has been encountered in their successful upkeep.

"The coal consumption in port has been reduced from 9.3 tons per day to 7.4 tons per day.

W. N. JEFFERS."

The following advantages of the submerged type have now been demonstrated in service:

(*a*) Lesser installation cost, due to fewer units.
(*b*) Lesser operating cost.
(*c*) Greater simplicity and superior reliability of operation.
(*d*) Greater thermal efficiency.
(*e*) Greater capacity.

In view of these results, it appears that the submerged coil type as developed at the Boston Navy Yard and installed on the U. S. S. *Denver* has a marked superiority of performance over other low pressure types being installed in the Navy, and that for future installations, whether on new vessels or conversions of existing high pressure plants, the submerged coil type is preferable.

U. S. S. *RALEIGH.*

DESCRIPTION AND TRIALS.

By Lieut. Comdr. H. R. Keller, U.S.N., Member.

Senior Engineer Officer.

The U. S. S. *Raleigh* was authorized by Acts of Congress dated August 29, 1916, and March 4, 1917. The original contract was entered into with the Union Iron Works of San Francisco, California on August 21, 1917, but on account of unsatisfactory progress the contract was forfeited on April 27, 1919. A contract was then made on June 12, 1919 with the Bethlehem Shipbuilding Corporation to construct and complete the two scout cruisers which the Union Iron Works had commenced. These two scouts known as scout cruisers Nos. 7 and 8 were built at the Fore River Plant of the Bethlehem Shipbuilding Corporation at Quincy, Mass., on a cost-plus fixed profit basis.

The contract cost was $6,500,000 plus a profit of $645,040. If the actual cost was less than the contract price an additional profit of one-third of the difference between the contract price and the actual cost was allowed.

The keel was laid on August 16, 1920, the vessel launched on October 25, 1922 and commissioned on February 6, 1924.

TYPE.

This ship is one of ten vessels of which there are now (June 1) eight in commission. In general there have been three classes sub-divided according to the builders; namely the Todd boats, the *Omaha, Milwaukee* and *Cincinnati,* built by the Todd Shipbuilding and Drydock Co.; the Cramp boats, the *Richmond,*

Concord, Trenton, Marblehead and *Memphis,* built by the William Cramp and Sons Ship and Engine Building Co.; and the Fore River Boats, *Detroit* and *Raleigh* built by the Bethlehem Shipbuilding Corporation at their Fore River Plant. The *Raleigh* is the second one of the scouts built at Fore River to be commissioned and is known as number seven.

This class of scouts is the only class to be authorized since 1908. They are practically the cruiser class of the Navy in which our Navy is very greatly deficient both in numbers and when compared to the 5-5-3 ratio. Eight of them will form two Light Cruiser Divisions attached to the Scouting Fleet. On account of the lack of destroyer leaders two of them will be used as such, one on each coast.

The *Richmond* has been described in the JOURNAL OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS, volume XXXV, No. 3 of August, 1923, and the reader is referred to that number for details of hull design which are duplicated on all the ships of the class. The *Omaha* has been described in the May, 1924, number of the JOURNAL of this Society. The machinery installation of the several classes of boats differ from each other so materially that a description of one does not apply to the others.

HULL DATA.

As minor changes in hull data influence engineering performance the hull characteristics of the Raleigh are shown below:

Length between perpendiculars, feet and inches	550–0
Length over all, feet and inches	555–6
Length on dead water line, feet and inches	550–0
Breadth molded extreme, feet and inches	54–10
Breadth outside of armor, feet and inches	55–4
Depth molded at side to upper deck amidships, feet and inches	34– ¼
Depth molded at center to upper deck amidships, feet and inches	34–11¼
Mean displacement to dead water line in tons	7100
Ratio length to beam	10
Displacement tons per inch at 13 feet 6 inches draft	50.6
Area dead water line plane, square feet	21,260

Number of frames, spacing 4 feet 0 inches	136
Coefficient of fineness, block	.610
Coefficient of fineness	.945
Coefficient of fineness, dead water line	.705
Capacity fuel oil tanks, gallons	544,982
Capacity reserve feed tanks—firerooms, Nos. 1 and 2, gallons	41,613
Capacity reserve feed tanks—firerooms, Nos. 3 and 4, gallons	53,602

APPEARANCE.

The appearance of the *Raleigh* is somewhat different from her predecessors in that her masts have been slightly lowered. All the scouts will eventually have lower masts than the original design. Also she has hawse pipes in place of the billboard for the stowage of anchors.

MAIN MACHINERY.

BOILERS.

There are twelve Fore River Yarrow boilers similarly located to the other ships of the class; *i.e.*, three boilers in each of four fire-rooms, two fire-rooms forward of the forward engine room and two fire-rooms between the forward and after engine rooms. The boilers were made at the Fore River Plant and are similar in design to those installed on the destroyers built at Quincy and at Squantum during the war program. The following data describes the boilers installed:

Working pressure, pounds per square inch	265
Test pressure	400
Length external, feet and inches	14–0
Width external, feet and inches	14–9¾
Number burners (all boilers) "Lodi"	48
"Mayflower"	24
Heating surface, square feet, per boiler	7507
Heating surface, square feet, all boilers	90,084
Drum diameter, steam, feet and inches	4–2
Drum diameter, water, feet and inches	2–6
Furnace volume per boiler (4 outboard boilers in firerooms Nos. 3 and 4), cubic feet	765
Furnace volume per boiler (all other boilers), cubic feet	838
Total furnace volume all boilers, cubic feet	10,764
Tubes per boiler 1 inch O.D. .095 inch thick	3436
Tubes per boiler 1¼ inch O.D. .109 inch thick	238

Size of brick floor, two layers, inches	1¼
Size of brick side, inches	4½
Size of brick back, inches	4½

SMOKE PIPES.

Number	1	2	3	4
Height smoke pipe of boilers above bottom of brick pans, feet and inches	76–10½	76–0⅞	72–5¼	72–3½
Area, square feet	63.62	63.62	63.62	63.62

FUEL OIL SYSTEM.

Fuel oil is stowed in tanks forward of the forward fire-room and abaft the after engine room; the "A" tanks holding approximately 335,600 gallons and the "D" tanks approximately 269,400 gallons, making a total capacity of approximately 545,000 gallons. Suction is obtained by booster pumps which discharge to the suction of the service pumps. The latter discharge through strainers, oil heaters and oil meters to the boilers at pressures usually carried between 200 pounds and 300 pounds per square inch.

RECIRCULATING SYSTEM.

As it will probably be necessary in time of war to burn heavier oils than those generally used at present, it has been found desirable to equip them for burning Bunker "C" oil. The latter is an oil having a flash point not lower than 150 degrees F. (Pensky Martens closed tested), a viscosity not greater than 300 seconds at 122 degrees F. (Saybolt Furol Viscosimeter) and is generally about 16 degrees Baumé gravity. In order to burn this oil special equipment has been installed on the *Raleigh* known as the Fuel Oil Recirculating System.

This system includes two additional pumps of the same type and size as those used for booster pumps and which are interchangeable with the latter. It also has two additional fuel oil recirculating heaters in fire-rooms one and three and appropriate piping and strainers between them and the tanks. Each

tank has a nozzle ring through which the warm oil discharges to heat up the remainder of the cold oil.

Suction is obtained by the recirculating pump and the oil which is at first cold is discharged through the recirculating heaters by a 6-inch recirculating discharge pipe to the oil nozzle rings in each tank above the suction. The tank oil is then gradually heated with resultant thinning so that the booster pump can discharge it through the regular heaters in the normal manner to the burners.

OIL BURNING.

All boilers are oil burning only. Each boiler is equipped with four Lodi burners manufactured by the Babcock and Wilcox Company and two turbine driven individual forced draft blowers.* The latter are unique and the *Raleigh* is the first scout to be partly equipped with these. They are known as the "Mayflower" burners from the fact that the first ship which received them was the President's Yacht *Mayflower.* The turbine casting fits into the boiler front just as the ordinary casting for a forced draft register and drives a 6-bladed fan enclosed within this casting. This fan is just in front of the impeller plate. The air register has both a longitudinal opening and a circumferential opening. The burner projects through the center of the turbine and fan. These burners are for use without the main blowers. The turbines were made by the B. F. Sturtevant Co., of Boston for the Babcock and Wilcox Co., who were the contractors for the assembly of the turbines and burners which are made by the latter. They are designed for a capacity of 3500 cubic feet of air per minute against a static head of 1½ inches of water.

FORCED DRAFT.

The forced draft blowers are identical with those installed on the *Richmond* and *Omaha* already described in the JOURNAL, except that the normal R.P.M. are 1400 instead of 1350 for those vessels.

* For complete description see JOURNAL this Society, May, 1924, Vol. XXXVI, No. 2.

STEAM FLOW METER.

Through the courtesy of the Bailey Meter Company, a Bailey steam flow, air flow and gas temperature recording meter has been installed on one boiler of this vessel. Indications are that such a meter will be a very valuable asset to ships of the future in analyzing the expenditure of their steam and securing the correct air flow for efficient combustion.

VENTILATION.

In order to ventilate the fire-rooms after securing the steaming boilers therein, an opening with a hinged and dogged air tight cover has been cut in the blower intake spaces of the center blower in each fire-room. By opening this space to the uptake enclosure, opening the fidley top manholes to the main deck, closing the blower hood for the center boiler and running either of the outboard blowers fresh air is forced into the fire-room and out through the uptake enclosure to the upper deck. This obviates the necessity of heating up the crews' living quarters on the main deck by allowing the heated air to leave by the air locks.

COMMUNICATIONS (FIRE-ROOMS).

Fire-room communication in the past has been almost an impossibility on ships of this class. On this vessel the lower part of the space on the port side which was originally a part of the air lock has been converted to a communication booth by the installation of a destroyer type of air tight manhole cover between the lower part of the original air lock and the first level above this.

All voice tubes and the ship's service telephones have been installed in this booth with their bells in the fire-room. The result has been to make easy communication either by voice tube or telephone.

MAIN ENGINES.

The main engines consist of four sets of turbines, each driving its own propeller shaft. Two of these in the forward engine room are connected to shafts one and four, and the two in the after engine room are connected to shafts two and three.

ARRANGEMENT.

Plate I shows the arrangement of the main engine and boilers, three forward boilers not shown.

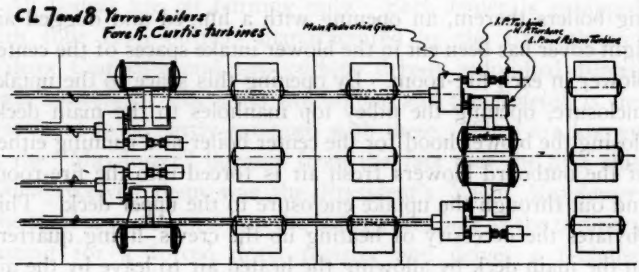


PLATE I.

TYPE.

Each set of turbines is a Curtis Three-Unit Geared Type almost identical with those installed on all Fore River and Squantum destroyers of the war program. The turbines are the High Pressure Turbine and the Intermediate Pressure Turbine driving the pinion on one side of a reduction gear and the Low Pressure Turbine driving the pinion on the opposite side of the reduction gear. The latter is also driven by the Astern Turbine which is in the forward end of the Low Pressure Turbine. The low pressure turbine is of the double flow type.

All turbines and reduction gear have Kingsbury thrust bearings, spherical self-aligning turbine bearings and forced lubrication.

TURBINE DATA.

	H. P.	*I. P.*	*L. P. Double Flow*	*Reverse*
Steam Inlet Main	13½ inch diameter	16 inch diameter	1-28 inch diameter	1-9 inch diameter
Steam Inlet Auxiliary	6 inch diameter	6 inch diameter	6 inch diameter	None
Steam Outlet	14 inches to L. P.	28 inch diameter	2-3 feet 6 inches ×	2-3 feet 6 inches
	16 inches to I. P.		7 feet 0 inches	7 feet 0 inches
Nominal Pitch Diameter	38½ to	40 inches	54 inches	41 inches to
	37 11/16 inches			36½ inches
No. of Stages	1-2 row and	7	5 each	2
	10 single			
Blade Lengths	2⅝ inches to	2¼ to	4½ inches to	1¼ inches to
	1 5/16 inches	8½ inches	12 inches	7½ inches
Designed R. P. M.	2500	2500	2500	2500
H. P. Designed	4960	6780	11,480	
Rotor Shaft Bearings	8 inches × 8 inches	8 inches × 8 inches	10 inch diameter, 14 inches long	

REDUCTION GEAR.

Maker—The Falk Co., Milwaukee, Wis.

	Pitch Diameter Inches	*No. of Teeth*	*Face Inches*
Gear	84.286	295	48 total
Pinion	13.429	47	48 total
Reduction Ratio			6.298 to 1
Main Gear Bearings	(2) 15 inch diameter, 12 inches long		
Pinion Bearings	4 each pinion 2–9¼ inch diameter, 9 inches long 2–9¼ inch diameter, 10 inches long		
Kingsbury	30 inches, 12 shoes		

THRUST BEARINGS (KINGSBURY).

No.	*H.P.*	*I.P.*	*L.P. and Astern*	*Main*
Collar, Outside Diameter, inches	8⅛	9⅛	8⅛	30⅜
Collar, Inside Diameter, inches	4½	5¾	4½	14.25
Collar, Thickness, inches	1	1	1	2½ 5¼
Number of Rings	2	2	2	2—4 halves
Shoes per Ring	8	8	8	6
Eff. Th. Area per Ring	19.328	18.104	19.328	447.66
Nominal Size, inches	8	9	8	30

OPERATION.

For low cruising speeds below 10 knots steam is admitted to the High Pressure turbine through a separate cruising nozzle, and above that speed the main throttles are used. The High Pressure, Intermediate Pressure and Low Pressure turbines may be operated either in series or in parallel. The economy by operating in series is greater than when in parallel; being at 15 knots approximately 65 per cent greater, at 20 knots approximately 24 per cent greater and at 22½ knots approximately 5 per cent greater.

The design is such that at speeds below about 18 knots the turbines may be operated in series with 100 per cent of the steam through the high pressure turbine, 100 per cent through the I.P. turbine and 100 per cent through the L.P. turbine. Above the limiting pressure for which the relief valve on the first stage of the high pressure turbine is set (120 pounds) a

by-pass valve must be cracked, opening from the first stage of the high pressure turbine to the first stage of the intermediate pressure turbine. This limiting pressure occurs at about 18 knots and may be relieved by gradually opening the by-pass valve until a speed of about 25 knots is reached. Above 25 knots parallel operation is necessary. This is accomplished by opening maneuvering valve "B" shown on plate III. When in this position 100 per cent of the steam passes through the first stage of the high pressure turbine after which it divides, 15 per cent going through the remaining stages of the high pressure turbine then direct to the low pressure turbine, 85 per cent goes through the by-pass from the first stage of the high pressure turbine to the intermediate pressure turbine from which it exhausts into the low pressure turbine. At the low pressure turbine the steam which has followed parallel paths reunites and divides again, 50 per cent flowing forward and 50 per cent aft.

The change from series to parallel or *vice versa* involves only the opening or closing of two valves. The series operation eliminates the use of clutches or idle turbines.

NOZZLES REQUIRED FOR VARIOUS SPEEDS.

Speed	Position of Cruising Throttle	Position of Ahead Throttle	Position By-pass A	Position Maneuvering valve B	Nozzles Open
0–10 knots.....	Open	Closed	Closed	Closed	None
10–12 knots.....	Closed	Open	Closed	Closed	None
12–15 knots.....	Closed	Open	Closed	Closed	One
15–20 knots.....	Closed	Open	Open Slightly	Closed	One
20–22½ knots...	Closed	Open	Open ½ turn	Closed	Two (1 and 2)
22½ to 25 knots	Closed	Open	Open 1 turn	Open	Two (1 and 2)
25 to 30 knots..	Closed	Open	Open 2 turns	Open	Three (1-2-3)
30 to full.....	Closed	Open	Open wide	Open	Six (1 to 6)

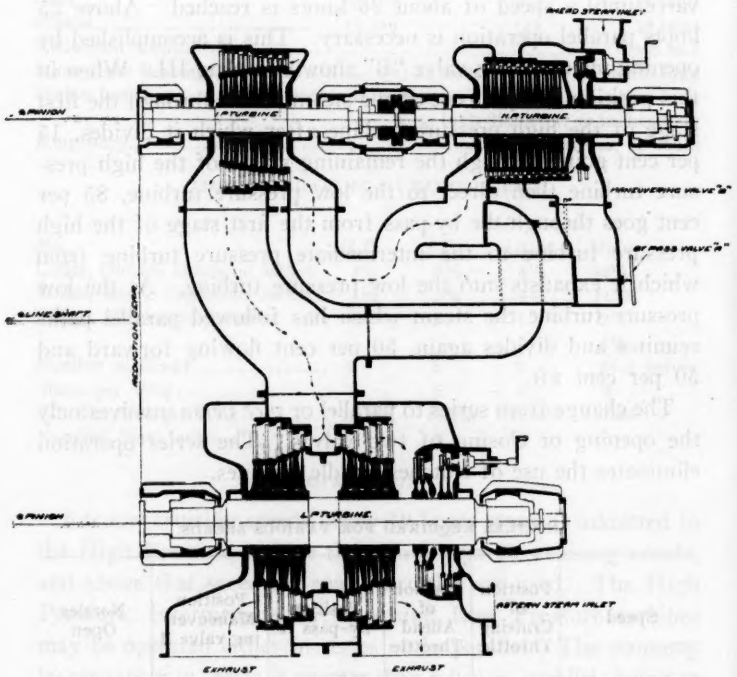


PLATE II.

OPERATING IN SERIES. SPEEDS FROM 10 KNOTS TO 18 KNOTS.

Note:—By-pass Valve "A" closed. Maneuvering Valve "B" closed.

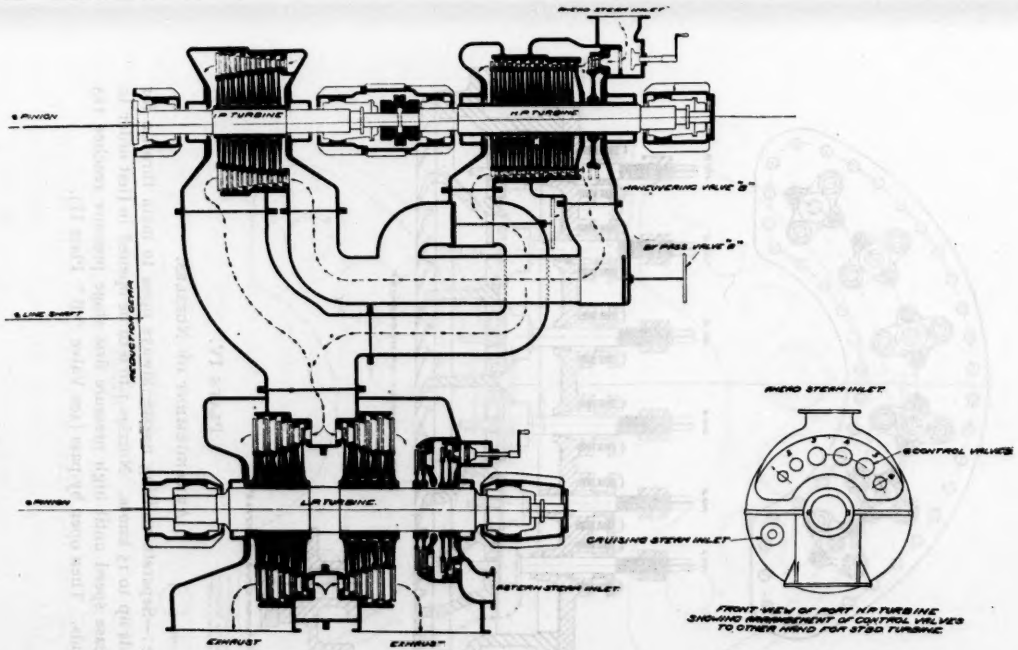


PLATE III.

OPERATING IN PARALLEL. SPEEDS ABOVE 18 KNOTS.

Note :—By-Pass Valve "A" open, 85 per cent steam takes this path. Maneuvering Valve "B" open to low pressure turbine, 15 per cent of steam takes this path.

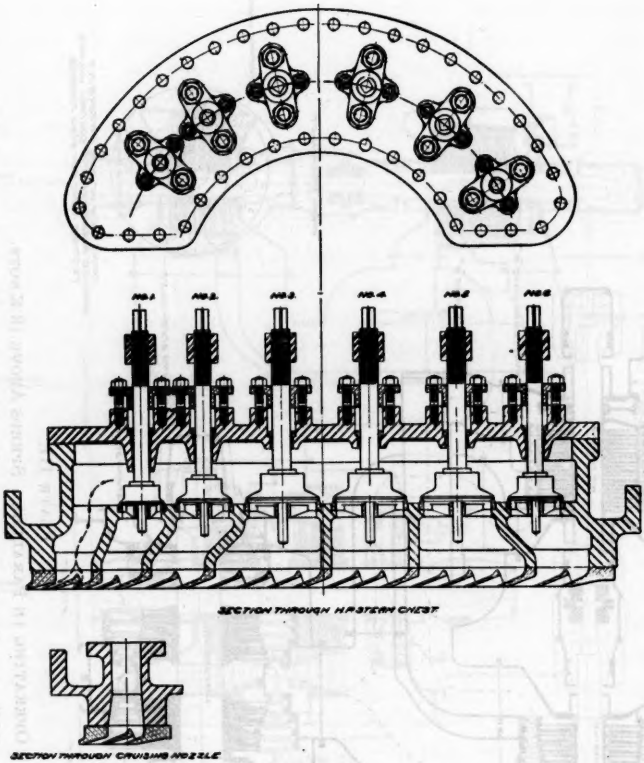


PLATE IV.

ARRANGEMENT OF NOZZLES.

Note:—Separate cruising nozzle, always open to main throttle for speeds up to 15 knots. Nozzles 1 to 6 to be opened in that order to increase speed until high pressure first stage pressure reaches 115 pounds. Then open by-pass (see Valve "B" Plate II).

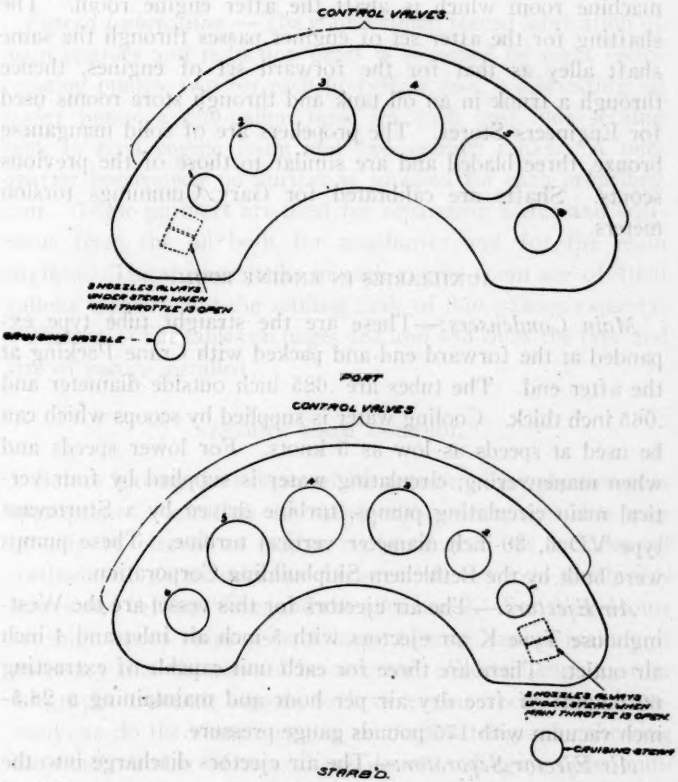

CONTROL VALVES.
1
2
3
4
5
6
8 NOZZLES ALWAYS UNDER STEAM WHEN MAIN THROTTLE IS OPEN
OPEN OVING NOZZLE
PORT
CONTROL VALVES
1
2
3
4
5
6
8 NOZZLES ALWAYS UNDER STEAM WHEN MAIN THROTTLE IS OPEN
CRUISING STEAM
STARB'D.

PLATE V.

SHAFTING AND PROPELLERS.

The shafting for the forward set of engines passes through the two after fire-rooms and the after engine room and enters a stern tube in a shaft alley below the evaporator and ice machine room which is abaft the after engine room. The shafting for the after set of engines passes through the same shaft alley as that for the forward set of engines, thence through a trunk in an oil tank and through store rooms used for Engineers Stores. The propellers are of solid manganese bronze, three bladed and are similar to those of the previous scouts. Shafts are calibrated for Gary Cummings torsion meters.

AUXILIARIES IN ENGINE ROOM.

Main Condensers:—These are the straight tube type expanded at the forward end and packed with Crane Packing at the after end. The tubes are .625 inch outside diameter and .065 inch thick. Cooling water is supplied by scoops which can be used at speeds as low as 5 knots. For lower speeds and when maneuvering, circulating water is supplied by four vertical main circulating pumps, turbine driven by a Sturtevant type VD 6, 30-inch diameter vertical turbine. These pumps were built by the Bethlehem Shipbuilding Corporation.

Air Ejectors:—The air ejectors for this vessel are the Westinghouse Type K air ejectors with 5-inch air inlet and 4-inch air outlet. There are three for each unit capable of extracting 60 pounds of free dry air per hour and maintaining a 28.5-inch vacuum with 175 pounds gauge pressure.

Air Ejector Separator:—The air ejectors discharge into the upper part of the air separator where the steam is condensed and with the water from the condensate pumps flows by gravity to the feed tank. Each engine room has one air separator.

Condensate Pumps:—There are eight main condensate pumps, two for each engine unit. These are Worthington pumps of 600 gallons per minute capacity against a 30-foot

head driven by a Sturtevant A-12 turbine. They are designed to operate at 1500 R.P.M. with 265 pounds steam pressure and 10 pounds back pressure. The suction to each pump is 10-inch diameter and the discharge 6 inches. These pumps will develop 25 B.H.P.

Forced Lubrication:—The conventional forced lubrication of main engines and reduction gears is provided by eight reciprocating pumps, two for each propelling unit, a lubricating oil cooler pump, a 700-gallon tank for each unit, one settling tank in each engine room and two storage tanks. A one-quarter horsepower oil purifier is supplied for each propelling unit. These purifiers are used for separating water and sediment from the oil both for auxiliaries and for the main engines. The storage tanks in each engine room are of 1000 gallons capacity and the settling tank of 850 gallons capacity.

Pumps:—The tables on pages 482 and 483 show the type and size of pumps installed.

ENGINE ROOM CONTROL.

Before leaving the subject of the main engine operation it is appropriate to mention the rather elaborate system that may broadly be classed as engine room control. It includes all methods of communication between the various machinery spaces and between them and the pilot house. For these scouts are high speed ships with a large turning radius making it necessary that the control be accurate. Electric engine order telegraphs transmit signals to both engine rooms simultaneously, as do the electric engine revolution telegraphs showing the exact number of revolutions desired. Engine order indicators are also installed in all fire-rooms. The after engine room answers to the forward engine room and the latter to the pilot house. In each engine room there are electric step by step revolution counters with indicators in the central station, the pilot house, and a set of indicators for the after engine room in the forward engine room. There is also an electric

Reciprocating Pumps.

Auxiliary.	No.	Make	Location	Steam Cyl.			Water Cyl.			Stroke inches
				No.	Dia. inches	Dia. Piston Rod inches	No.	Dia. inches	Dia. Piston Rod inches	
Lubricating Oil	8	Worthington Vert. Simplex	2 each E.R.	1	8	1-5/8	1	12	1-5/8	12
Fire and Bilge	6	Worthington Vert. Simplex	1 FR#2 2 ER#1 1 FR#4 2 ER#2	1	10	1-7/8	1	9	1-7/8	12
Fuel Oil Service	8	Worthington Vert. Simplex	2 each F.R.	2	5-1/2	1-1/4	2	4	1-1/4	8
Fuel Oil Recirc. & Fuel Oil Serv.	4	Warren Single Vert.	2 FR#1 2 FR#3	1	12	2	1	10	2	18
Auxiliary Feed	4	Worthington Vert. Simplex	1 each F.R.	1	16-1/2	2-7/8	1	11	2-7/8	18
Reserve Feed	2	Worthington Vert. Simplex	1 each E.R.	1	7	1-7/16	1	7	1-7/16	12
Aux. Condenser	2	Worthington Feather Weight	1 each E.R.	1	7-1/2	1-1/2	1	14	1-1/2	12
Air Compressor	2	Westinghouse	1 FR#2 1 FR#4	1	11	1-3/4	1	11	1-3/4	12

Rotating Pumps.

Rotating Pumps.											
Auxiliary	No.	Make.	Location	Drive, Type	Dia. Suc. inches	Dia. Dis. inches	Dia. Wheel inches	Dia. Imp. inches	R.P.M.	G.P.M.	B.H.P.
Main Circulator	4	Bethlehem S.B. Co.	2 each E.R.	Sturtevant VD-6 Turbine	19-1/2	16	30	30	1400	11300	
Main Condensate	8	Worthington DS-Volute	4 each E.R.	Sturtevant A-12 Turbine	10	6	12	12	1500	600	25
Main Feed	4	Worthington 3 Stage	2 each E.R.	Sturtevant C-12 Turbine	6	5	24	11-7/8	3100	600	232
# Lub. Oil Cooler Circulating	2	Worthington Class BS	1 each E.R.	Sturtevant A-12 Turbine	9	8	12	9-1/2	2400	1500	24
Aux. Condenser Circulating	2	Worthington Volute double suction	1 each E. R.	Sturtevant A-12 Turbine	6	5	12	8	2400	1350	24
				Electric Auxiliaries.							Volts Amps.
Lubricating Oil Booster	2	Bethlehem S.B.Co.	F.E.R.	Diehl Motor	8	3-1/2		8-1/8	950	300	120 15
Lubricating Oil Purifier	4	DeLaval Separator No.300	2 each E.R.	Diehl Motor G401					1750	17	120 6.5
Turning Gear	3	General Electric	1 ER#2 2 ER#1						1500		7-1/2

Used for lubricating oil cooling, air separator, circulating water and gland exhauster condenser circulating water.

The table below gives data on heat transfer apparatus on board:

	No	Location.	No	TUBES			Surface.	
				Thickness inches	O.D. inches	Length feet and inches	Each sq.ft.	Total sq.ft.
Air Separator	2	1 each ER	326	.065	.625			
Gland Exh. Condenser	2	1 each ER	95					
Main Condenser	4	2 each ER	4559	.049	.625	14-8-1/2	10815	43260
Aux. Condenser	2	1 each ER	1021	.065	.625	6-2-1/16	1000	2000
F. W. Heater	4	1 each FR	708	.049	.625	3-4-1/8	637	2548
F. O. Heater	18	3 each FR	102	.072	.625	4-4-3/8	58.4	7008
F. O. Recirc. Heater	4	2 FR 1A3	156	.049	.625	4-4-3/4	105.3	421.1
L. O. Cooler	8	4 each ER	390	.049	.625	7-4	455	3640
Evaporator	4	Evap. Room	105	.065	1.5	3-5-3/4	253	1012

voltmeter type of revolution indicator which shows instantaneously in the forward engine room the R.P.M. of each shaft and in the after engine room the R.P.M. of shafts No. 3 and No. 4. In addition to these indicators there is in the after engine room a Smith-Cummings averaging counter showing the speed of each shaft and the average of all shafts. In the forward engine room the Smith-Cummings instrument shows the R.P.M. of shafts No. 1 and No. 4 only and the average for these. A system of tell-tales allows the throttleman on No. 4 shaft to synchronize his R.P.M. with the leading shaft, No. 1. No. 2 synchronizes with No. 1 through a similar tell-tale in the after engine room and No. 3 with No. 2 so that it is simple for each throttle operator to follow the lead set by No. 1 shaft.

A master smoke indicator for all fire-rooms shows in the forward engine room the kind of smoke from each stack when the transmitter on the bridge is turned to the proper indicator. A repeater shows each fire-room whether the smoke from its stack is clear white, light black or heavy black as an indication of the combustion being obtained.

An electric rudder angle indicator is also located in the forward engine room.

Each engine room has a sound proof booth with telephones to all parts of the ship paralleled by voice tubes to necessary compartments so that communication is adequate and reliable at all times.

Gland Exhauster:—The main turbine glands are of the usual labyrinth type fitted on Fore River Curtis Turbines. In order to reduce the loss of fresh water occasioned by the "feather" of steam blowing into the engine room as well as to decrease the humidity in the engine room, a gland exhaust system has been installed in each engine room. Each gland is fitted with a hood from which a small pipe leads to a small straight tube condenser taking its circulating water from the lubricating oil cooler pump. A fan driven by a four-tenths horsepower motor draws the vapor from the pipes above mentioned to the condenser from which the fresh water condensed flows by gravity to a reserve feed tank. A vapor outlet from the fan casing leads to the top of the feed tank.

ELECTRIC SALINITY SYSTEM.

As an adjunct to the main and auxiliary condensers, as well as for the distilling plant, an electric concentration salinity indicating system with signal light controllers is installed with cell connections for each main and auxiliary condenser, distillate, and brine from evaporators. By means of this system the salinity of the water in the condensers or that distilled by the evaporators is known instantly. This equipment is described in the JOURNAL OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS, Vol. XXXV, No. 3, page 526 (August, 1923).

AUXILIARIES OUTSIDE OF ENGINE ROOMS AND FIRE ROOMS.

EVAPORATORS AND ICE MACHINES.

When one, used to the old time evaporators, learns of evaporators and ice machines being in the same room, he is apt to wonder "what next." But this is actually the installation on here and furthermore this compartment is probably as com-

Evaporator Plant Auxiliaries.

Pumps.

Purpose	No.	Manufacturer	Type of Drive	G.P.M.	R.P.M.	Suct. inches	Disch. inches	Impellor Dia. inches	Amperes	Volts	H.P.
Distiller Circ.	2	Buffalo Pump Company	Gen. Elec. R A M 32 Form A	1000	850 to 1700	8	6	10-1/2	110	147	20
Distiller Air	2	Bethlehem S.B.Co.	Gear Electro Dynamic Company	14-inch piston, two 1-3/4 rods, 12-inch stroke.							
Brine Circ.	4	Bethlehem S.B.Co.	Gen. Elec. Dir. Cur. R A-26 A Form F 1	200	575 to 1150	4	3	8	7.5 to 13.8	125	3/4 to 1-1/2
Brine Overboard	2	Buffalo Pump Company	Gen. Elec. Dir. Cur. R A-27 A Form A 1	30-40	850 to 1700	2-1/2	2	7-1/4	2.1 to 15.7	120	1-1/2 to 2
Fresh Water	2	Buffalo Pump Company	Gen. Elec. Dir. Cur. R A-27 A Form A 1	30	850 to 1700	2-1/2	2	7-1/4	12.1 to 15.7	120	2

fortable as any one on the ship. This has been accomplished by the substitution for the former type of high pressure evaporator, a modified Lillie Low Pressure Vacuum Evaporator. (This type was described in the JOURNAL, Volume XXXV, No. 2, May, 1923.)

There are two units each containing a first effect and a second effect evaporator with duplicate auxiliaries which are interchangeable with either set. The capacity of the plant is approximately 33,000 gallons per day. All auxiliaries are electric driven. The details are listed on page 486.

Evaporators and Distillers.						
	Tubes.					
	No.	Thickness Inches	Outside Dia. In.	Length ft. and inches	Surface each sq. ft.	Total
Evaporators	184	.065	1-1/2		238.5	954
Distillers Straight Tube	488	.049	5/8	3 01/2	230	460

ICE MACHINES.

The evaporators are on the starboard side of a compartment abaft the after engine room and the ice machines on a platform one grating level above the evaporators near the port side of the same compartment. There are two ice machines of the Audiffren Singrun type furnished by the H. W. Johns-Manville Company. These are rated at 2 tons each per 24 hours. They are driven by two 5-horsepower General Electric Motors. The ice making capacity with the temperature of sea water at 60 degrees is about 24 twenty-five pound cakes of ice every 24 hours for each machine.

TRIALS.

The contract for the *Raleigh* and the *Detroit* provided that only one vessel of the two need be subjected to the thorough trials required. Accordingly the *Detroit* being the first vessel

of these two to be completed, was given the standardization trials, fuel consumption runs, and endurance runs specified in the contract. These resulted in a substantial bonus for the contractors which was duplicated for each vessel based on the performance of the first one.

The *Raleigh* made a 4-hour full power run using the data from standardization of the *Detroit* and made an average of 34.63 knots, developing 97,722 horsepower. The engine room and fire-room data are shown in tabular form below.

"RALEIGH" TRIAL DATA.

Date	22 December, 1923
Duration, hours	4
R. P. M.	382.64
Speed, knots	34.63
Displacement, tons	7197.9
S. H. P.	97,722
Boiler H. S., square feet	90,084
Pounds oil per hour	91,485.16
Pounds oil per knot on basis of 19,500 B. T. U. per pound	2641.79
Pounds oil per S. H. P. per hour of 19,500 B. T. U. per pound	.936

ENGINE ROOMS.

	Forward Engine Room.		*After Engine Room.*	
Shafts	1	4	2	3
Horsepower	23,665	24,939	25,863	23,256
R. P. M.	375.89	379.09	385.49	390.08

PRESSURES.

Main steam, pounds, gauge.	261	261	253	259
H. P. turbine, pounds, absolute	251	241	239	255
H. P. first stage, pounds, absolute	116	125	123	125
I. P. turbine, pounds, absolute	109	108	118	107
L. P. turbine, pounds, absolute	23	24	25	27
Vacuum inches, mercury..	27	26.8	27.3	28

TEMPERATURES DEGREES F.

	Forward Engine Room.		*After Engine Room.*	
Shafts	1	4	2	3
Injection	44	44	44	44
Discharge	88	88	82	79
Exhaust trunk	117	118	—	115
Water from oil cooler	51	54	59	59

	Forward Engine Room.	*After Engine Room.*
Condensate to separator	78	58
Condensate from separator	111	91
Feed tank	120	78
Oil to cooler	118	116
Oil from cooler	90	91

BEARINGS TEMPERATURES DEGREES F.

	Forward Engine Room.				*After Engine Room.*			
	No. 1		No. 4		No. 2		No. 3	
	Fwd.	Aft.	Fwd.	Aft.	Fwd.	Aft.	Fwd.	Aft.
H. P.	115	127	119	127	128	132	127	127
I. P.	128	117	128	121	132	121	128	123
L. P.	126	138	129	140	131	143	129	137
Main thrust	109		105		131		116	

ENGINE ROOM AUXILIARIES.

TURBINE DRIVEN PUMPS.

	R. P. M.	*Discharge Pressure pounds gauge*
Lubricating oil cooler circulating	972	
Condensate No. 1 Unit	1279	
No. 2 Unit	1317	
No. 3 Unit	1358	
No. 4 Unit	1274	
Main Feed No. 1 Unit	2900	302
No. 2 Unit	2854	306
No. 3 Unit	2729	309
No. 4 Unit	2750	294

RECIPROCATING PUMPS.

	Double Stroke.	*Pressure pounds, gauge.*
Lubricating Oil Pump No. 1 Unit	45	15
No. 2 Unit	42	15
Fire and Bilge	29	42

FIRE-ROOMS.

BOILERS.

Boiler No.	Pressure, pounds, gauge	No. burners	Oil pressure, pounds, gauge.	Oil temperature, degrees F.	Temp. gases by Pyrometer degrees F.	Blowers, R. P. M.
1	271	6	213	158	880	1351
2	268	6	207	157	680	1329
3	273	6	208	154	556	1598
4	275	6	268	147	799	1538
5	260	5	272	146	724	1538
6	267	6	238	143	810	1534
7	270	6	234	176	774	——
8	270	6	238	173	755	——
9	270	6	238	175	782	——
10	259	5.9	217	160	832	1461
11	256	5.6	224	163	767	1465
12	260	6	237	164	821	1398

TEMPERATURES AND PRESSURES.

Fire rooms No.	1	2	3	4
Air pressure, inches, water	6.3	8.4	7.5	7.7
Fuel oil pressure to strainer, pounds, gauge	—	281	288	139
Fuel oil pressure from strainer, pounds, gauge.	—	278	287	139
Auxiliary exhaust pressure on feed heater, pounds, gauge	—	9.5	9.1	8.0
Temperature oil to heater, degrees F.	95	87	91	66
Temperature oil from heater, degrees F.	155	144	178	87
Temperature feed water, degrees F.	—	218	219	220
Temperature fire room floor plates, degrees F.	94	99	117	101
Temperature fire room gratings, degrees F.	—	99	96	112

After the completion of the full power trial a 45-minute run was made using "Mayflower" burners only. At the time of the trials this installation was completed in three fire-rooms the data for which is shown below:

Duration of run	45 minutes
R. P. M., average, four shafts	199.22
Speed, knots	21.23
S. H. P., average	14,743
Boiler H. S., square feet	67,563
Pounds oil per hour	18,591.59
Pounds oil per knot on basis of 19,500 B. T. U. per pound	875.72
Pounds oil per knot S. H. P. per hour of 19,500 B. T. U. per pound	1.261

ENGINE ROOMS.

	Forward Engine Room.		*After Engine Room.*	
Shafts	1	4	2	3
Horsepower	3614	3845	3617	3667
R. P. M.	196.56	199.24	199.95	201.12
	Pressures.			
Main steam, pounds, gauge.	266	266	263	268
H. P. turbines, pounds, absolute	275	265	265	273
H. P. first stage, pounds, absolute	47	40	69	70
I. P. turbine, pounds, absolute	15	15	23	21
L. P. turbine, pounds, absolute	4.8	6.0	6.0	6.2
Vacuum, inches	29.0	29.2	28.7	29.6

TEMPERATURES DEGREES F.

	Forward Engine Room.		*After Engine Room.*	
	No. 1	No. 4	No. 2	No. 3
Injection	48	48	48	48
Discharge	96	86	92	99
Exhaust trunk	117		115	118

	Forward Engine Room.	*After Engine Room.*
Condensate to separator	52	44
Condensate from separator	100	87
Feed tank	123	89

The following table shows the performances of the *Detroit* on trial which are similar to that which might be expected of the *Raleigh:*

Speed	Full	30	25	20	15	10
Duration hours	4	4	6	4	4	4
Speed knots	34.63	30.09	24.89	20.03	15.20	9.81
Displacement tons	7187.4	7207.4	7216	7159.7	7183	7221.7
Average R. P. M.	382.89	293	240.41	188.46	140.49	91.21
No. boilers in use	12	12	12	6	2	2–3
Total oil consumed (19,500 B. T. U.)	91,318.8	43,585.6	25,334.95	12,799.56	7277.46	3989.65
Oil consumed per square foot heating surface per hour	1.014	.484	.281	.284	.485	
S. H. P. trials	97,370	48,813	24,498	11,271	4726	1352
Guaranteed oil consumed, pounds per S. H. P. per hour	1.113					
Actual oil consumed, pounds per S. H. P. per hour	.938					2.951*
Slip in per cent	22.8	12.65	11.12	8.4	7.67	7.16
Water consumed per hour, pounds	637,402†	352,895*	175,944*	94,163†	40,270*	
Water consumed per S. H. P. per hour, pounds	13.19*	14.41*	15.61*	19.92†	29.78*	
Pounds water evaporated per pound of fuel	14.62			12.94		
Pounds water per square foot H. S.	7.08			6.27		

* Main engines.

† All machinery.

FIRE-ROOMS.

Boiler No.	Pressure, pounds, gauge.	No. burners	Oil pressure, pounds, gauge.	Oil temperature, degrees F.	Temp. gases by Pyrometer, degrees F.
1	258	2	144	146	623
2	250	1.5	180	143	638
3	265	2	174	140	435
7	270	2	175	156	553
8	270	2	175	158	680
9	270	2	171	154	680
10	255	2	145	168	625
11	255	2	145	176	523
12	260	2	169	160	502

BLOWERS R.P.M.

No. 2 788 No. 12 1270

Blowers were run for ventilation.

In conclusion it may be stated that the Scout Cruiser *Raleigh* met the expectation of the builders and that she is a credit both to the Fore River Plant and to those responsible for her inspection while building. She adds one unit to the small number of scout cruisers in which the U. S. Navy is greatly deficient.

HEAT TREATMENT OF NICKEL STEEL TURBINE BLADING.

By Commander Carlos Bean, U. S. N., Member.
Inspector of Machinery, Quincy, Mass.

To produce material of the necessary strength and elasticity to withstand the shocks due to high velocity steam and stresses due to the high rotative speed of the modern turbine has been one of the greatest problems of turbine design.

A careful study of the subject has been undertaken at the Fore River Plant of the Bethlehem Steel Company. The methods used and the results of this investigation are here presented and may be grouped under the following headings:

1. Determination of critical temperature of nickel steel.
2. The Electric Furnace.
3. The forms of test specimens.
4. Results of various forms of heat treatment.
5. Method of forging the blades.

DETERMINATION OF CRITICAL RANGES.

In this experiment a Hoskins experimental electrical furnace was used. The current consumed was 1.36 ampères at 220 volts.

After experimenting with several types of specimens, the two types shown were adopted; Figures 1 and 2.

Fig. 1.

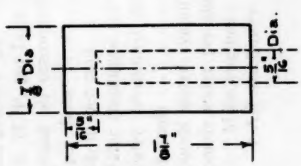
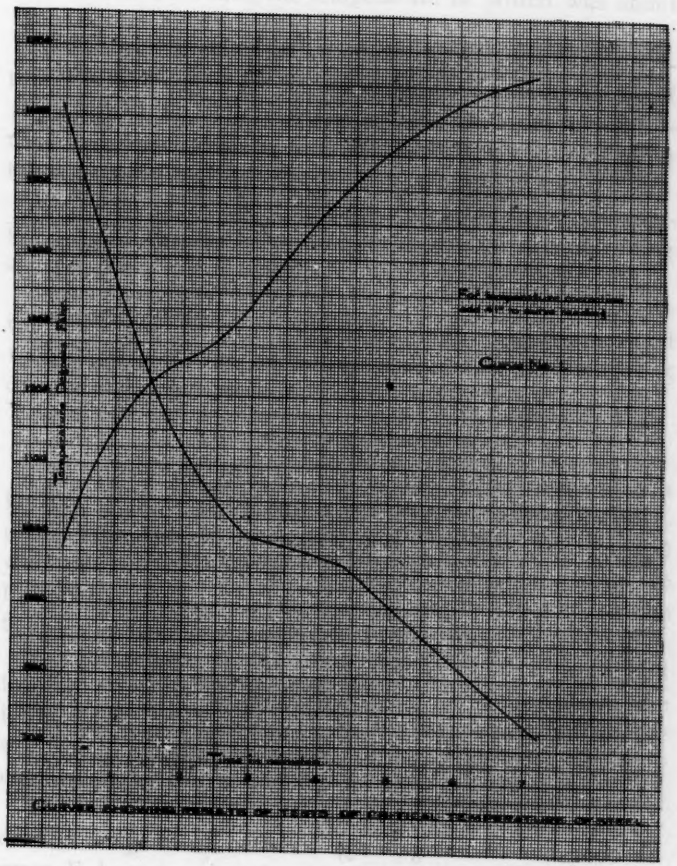
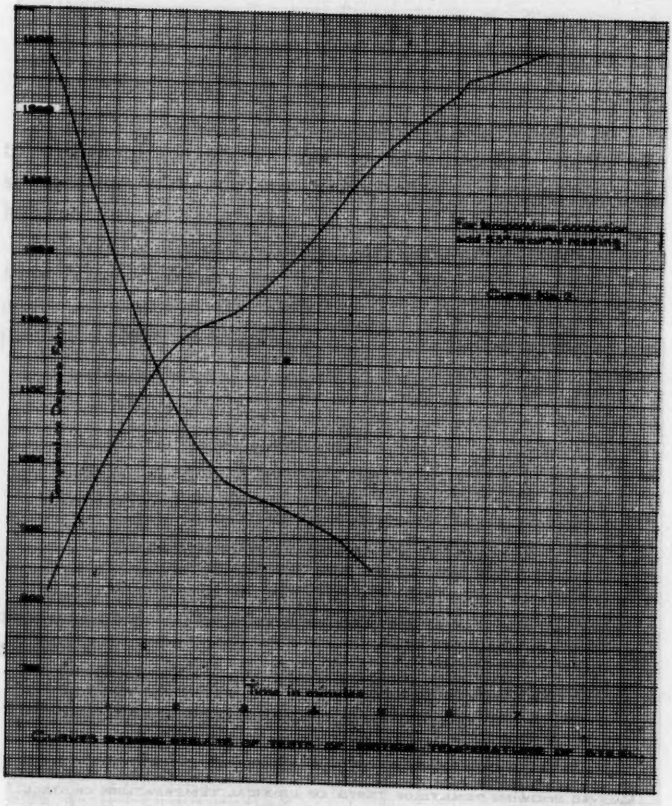


Fig. 2





The bare pyrometer point was pushed to the bottom of the hole and packed in with asbestos. Each test piece was heated to about 1000 degrees F., and they were then placed in the electric furnace, the temperature of which was about 1700 degrees F.

The elapsed time between each 20 degrees rise in temperature was taken until the test piece attained a temperature of 1650 degrees F. The piece was then taken out of the furnace and cooled in the air. Elapsed time readings being taken between each 20 degrees drop in temperature.

Each form of test specimen indicated the same characteristics. The results of the tests are shown on accompanying curves.

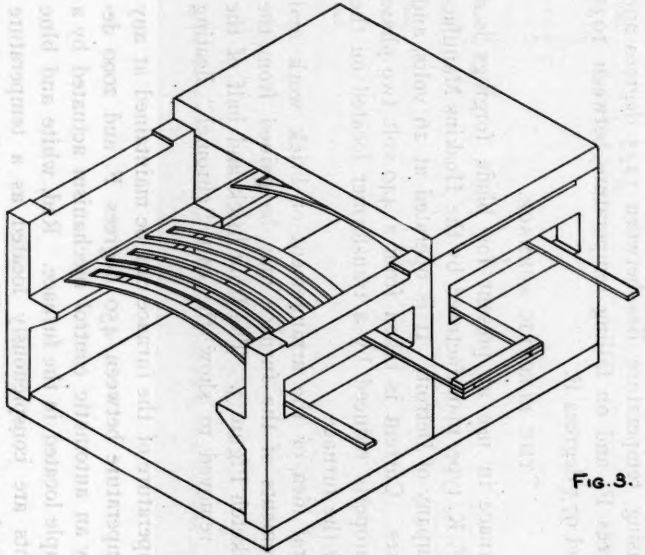
Inspection of the curves indicates that the critical temperature on rising temperature lies between 1235 degrees and 1300 degrees F., and on falling temperature between 1035 degrees and 975 degrees F.

THE ELECTRIC FURNACE.

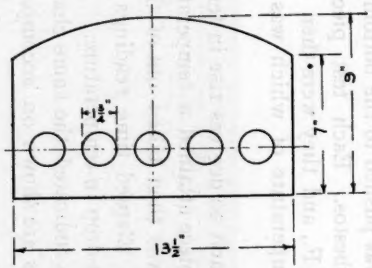
The furnace in use at present for blade forgings is a Hoskins F. K. type, manufactured by the Hoskins Manufacturing Company of Detroit. It is operated at 26 volts, and 500 ampères. Current is taken from a 440 volt two phase line and properly reduced by a transformer located on the floor below the furnace.

A general idea of the arrangement of brick work and heating elements of the furnace may be gained from the isometric sketch Figure 3. The front brick and half of the top being removed to show the cast "chromel" heating elements.

The temperature of the furnace can be maintained at any desired temperature between 450 degrees F. and 2000 degrees F. by an automatic control mechanism actuated by a thermo couple located in the furnace. Red, white and blue signal lights are conspicuously located as a temperature guide to the hammer operator. The external dimensions of



Arrangement of interior of electric furnace with brickwork partially removed showing cast "chromel" heating elements.



Elevation of front furnace brick showing openings through which stock is placed in furnace.

FIG. 3.

HOSKINS ELECTRIC FURNACE.

the furnace outside of the casing are 37 inches × 32 inches × 32 inches; the internal dimensions are 24 inches × 14 inches × 8 inches.

The results of a few experiments with the furnace may be of interest.

(*a*) With the furnace empty the temperature was raised from 200 degrees to 1860 degrees F. in two hours.

(*b*) Five (5) nickel steel bars 1 inch × ⅛ inch were put into the furnace through small openings in the front fire brick. The temperature fell to 1710 degrees F., but rose to 1860 degrees F. in thirteen (13) minutes, with the bars thoroughly heated. In this test, 16.1 pounds of nickel steel were raised from room temperature to 1860 degrees F. in thirteen (13) minutes.

(*c*) With same bars in the furnace, the regulator was set for 1950 degrees F. In five (5) minntes, the furnace and bars showed 1950 degrees F.

(*d*) With a furnace temperature of 1950 degrees F., five cold bars were inserted and the temperature fell to 1900 degrees F., but rose in (6) minutes to 1950 degrees F.

(*e*) The empty furnace was heated to a temperature of 1950 degrees F. with door closed. Fifteen and one-half (15½) hours after the current was shut off the temperature dropped to 460 degrees F.

(*f*) From a temperature of 1300 degrees F., the fall in temperature at various elapsed times was as follows:

	15½	minutes	1200 degrees F.
	44	minutes	1100 degrees F.
1 hour	14	minutes	1050 degrees F.
1 hour	31	minutes	1020 degrees F.
2 hours	0	minutes	970 degrees F.
2 hours	12	minutes	950 degrees F.
2 hours	44	minutes	910 degrees F.
14 hours	6	minutes	400 degrees F.

TENSILE TEST SPECIMENS.

The first test specimens used were machined from a bar which had been forged down to 1 inch diameter and heat treated. The specimens were machined to standard form 2 inches long between prick punch marks and .505 inch diameter. Owing to the fact that the 1 inch diameter piece does not receive a reduction of area equal to the blade forging, and hence does not accurately represent the finished blade section a new design of the form shown in Figure 4 was

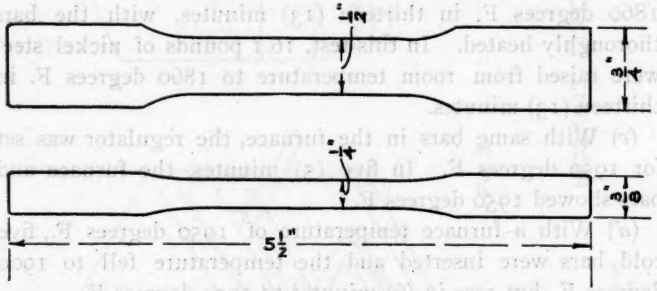


FIG. 4

tried. This specimen was forged to final size in a die and pulled in the machine as it left the die without machining. Owing to the difficulty met in holding this specimen in the jaws of the testing machine, a third specimen of the form shown in Figure 5 was tried. While no difficulty was experienced in holding this specimen in the jaws of the testing machine, the results obtained were not uniform owing to the presence of scale and the fins left by the dies.

In order to produce a specimen without fins, a new set of dies was built with which to forge a round section specimen .6 inch in diameter 2 inches between prick punch marks, and with standard ends for test machine jaws. The material forged to this size receives about the same reduction as the blade forging. Before testing, this specimen was turned to

standard .505 inch diameter. Material for this specimen was taken from the $2\frac{5}{8}$ inch tapered portion of the blank forging. See Figure 6.

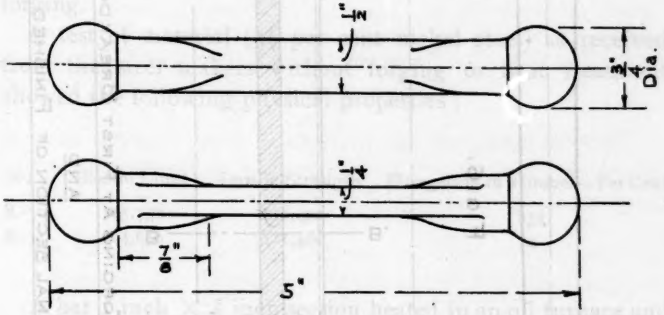


FIG. 5

Results obtained with this form of specimen were not uniform and investigation seemed to indicate that the flow of metal in the dies was restricted on account of the enlargements at the ends of the specimen for holding in the testing machine.

The specimen which was next tried was taken from the wheel end of the blade after final forging and treating. A section 3 inches long is cut from the blade and turned to a diameter of .305 inch and a length between prick punch marks of 1.2 inch to 1.5 inch. Results obtained with this specimen and methods of heat treatment are shown in table on page 510.

The physical requirements desired of turbine blading material are as follows:

Elastic limit 65,000 pounds per square inch.
Tensile strength 95,000 pounds per square inch.
Elongation 25 per cent in two inches.

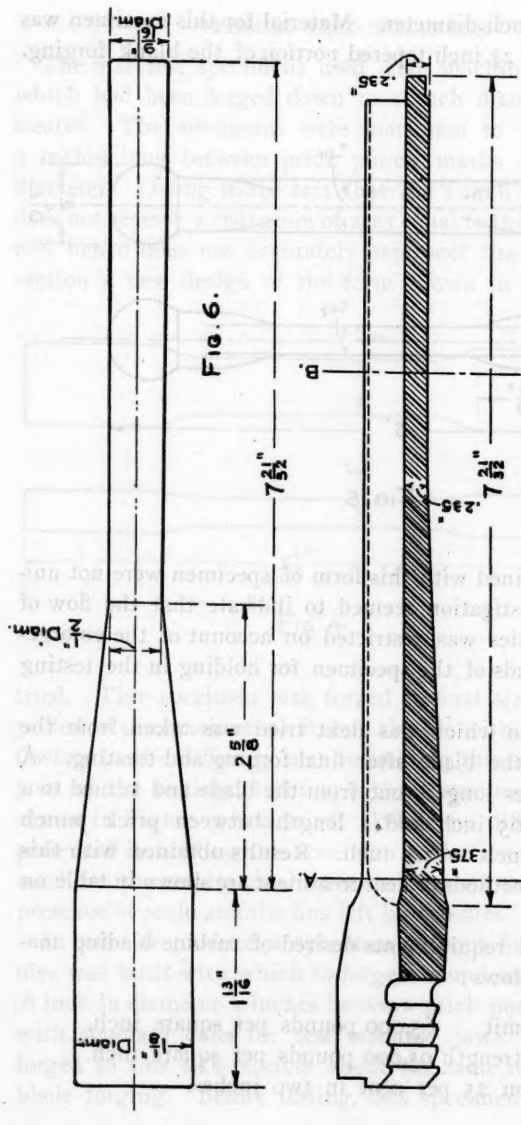


FIG. 6.

BLANK FORGING AT FIRST BREAKDOWN

AND

LONGITUDINAL SECTION OF FINISHED BLADE.

Sectional area of 1/8" x 1" bar from which blades are forged .875 sq.in.

Sectional area of blade at A-A. .294 sq.in.

Sectional area of blade at B-B. .211 sq.in.

In the following tests the specimens are given a serial number preceded by a letter. R—designating a round specimen of standard dimensions; F—a flat specimen (figure 4); B—a specimen .305 inch diameter taken from the bucket forging.

A test of material ($3\frac{1}{2}$ per cent nickel steel) as received from the steel makers without forging or heat treatment showed the following physical properties:

No.	Elastic Limit	Tensile Strength	Elongation in 2 inches—Per Cent
R-30	105,750	111,400	$23\frac{1}{2}$
R-31	104,650	111,400	24

A bar 1 inch $\times$ $\frac{7}{8}$ inch section heated in an oil furnace and forged to 1 inch round showed the following properties:

R-16	92,450	109,900	$17\frac{1}{2}$

Flat specimens heated in oil furnace to 1950 degrees—2000 degrees, forged to test bar dimensions, and tested without heat treatment gave the following results:

No.	Elastic Limit	Tensile Strength	Elongation Per Cent
F-I	71,040	116,080	17
F-II	62,960	117,200	16
F-III	62,400	127,920	19

Heat treatment of nickel steel above the critical range. Slow cooling in furnace from 1600 degrees F. produced steel low in elastic limit and tensile strength and high in elongation.

No.	Elastic Limit	Tensile Strength	Elongation Per Cent
R-I	58,000	82,650	$29\frac{1}{2}$
R-II	55,300	81,900	29

Cooling in air produced material as indicated below:

No.	Temperature	Elastic Limit	Tensile Strength	Elongation Per Cent
R-14	1550	95,150	106,000	19
R-13	1500	.....	104,450	20
R-12	1450	91,250	103,200	23
R-11	1400	94,150	102,400	23

Material heated in oil furnace at 1900 to 2000 degrees forged, and heat treated for one hour in oil furnace at various temperatures produced results as follows:

No.	Temp. of Heat Treatment	Elastic Limit	Tensile Strength	Elongation Per Cent
F-6	1610	87,200	114,080	18
F-5	1550	72,320	113,680	19
F-4	1450	64,880	107,920	19
F-3	1400	60,000	109,350	19
F-8	1350	66,560	108,720	23½
F-1	1300	66,000	99,680	20
R-4	1306	93,250	101,050	22
R-5	1386	86,600	99,600	24

Material forged, heat treated from 45 to 60 minutes at various temperatures and cooled in box of ashes. In this experiment, a box of the proper size was filled about half full of ashes. The heated specimens were placed upon the surface of the ashes but were not covered. The sides of the box in this test acted as shields against air currents upon the specimens.

No.	Treat. Temp.	Elastic Limit	Tensile Strength	Elongation Per Cent	
F-41	1600	67,600	105,680	22	Oil Furnace
F-43	1460	71,360	108,640	21	
F-45	1350	63,280	110,640	25	

No.	Treat. Temp.	Elastic Limit	Tensile Strength	Elongation Per Cent	
F-49	1325	71,840	99,040	20	Electric Furnace
F-59	1325	82,880	105,200	22	
F-60	1325	74,160	106,440	19½	

Two specimens below were forged and heat treated for one hour in the electric furnace at 1350 degrees F.:

No.	Elastic Limit	Tensile Strength	Elongation Per Cent
F-35	60,560	93,920	27
F-36	62,720	93,440	27

For the purpose of ascertaining the final effect of various forms of treatment upon the specimen after forging and before heat treating, a series of experiments was tried with results as shown in accompanying table. All specimens were cooled with the furnace from a temperature of 1325 degrees F.:

Method of Forging and Cooling Before Heat Treatment	Number	Elastic Limit	Tensile Strength	Elongation Per Cent
Electric furnace, forged and cooled on cold plate	F-93	71,200	85,700	26½
	F-94	66,000	84,000	26½
Electric furnace, forged and cooled on the ground	F-97	61,500	87,100	26
	F-99	62,800	86,200	26
Electric furnace, forged and cooled in furnace with door open	F-103	66,800	81,900	21
	F-104	58,800	84,300	21½
Oil furnace, forged at 1950 degrees cooled in ashes	F-105	66,500	90,000	24
	F-106	60,000	88,200	20
Oil furnace, forged at 2050 cooled in ashes	F-109	62,500	88,300	24
	F-110	60,600	88,000	21

This series of experiments was continued; cooling taking place in ashes from a temperature of 1275 degrees F.:

Method of Forging and Cooling before Treatment	No.	Elastic Limit	Tensile Strength	Elongation Per Cent
Forged in electric furnace at 1940 degrees, dropped in water	F-91	81,500	100,500	22½
	F-92	77,500	95,000	20
Forged in electric furnace 1940 degrees and dropped on steel plate	F-95	71,400	91,900	22
	F-96	74,800	94,300	21
Forged in electric furnace at 1940 degrees and dropped on ground	F-98	68,000	92,000	21
	F-100	70,500	92,700	24
Forged in electric furnace at 1940 degrees cooled in furnace with door open	F-101	65,000	85,000	21
	F-102	64,600	90,700	22
Forged in oil furnace at 1950 degrees, cooled in ashes	F-107	60,600	92,300	23
	F-108	56,880	93,200	24
Forged in oil furnace at 2050 degrees and cooled in ashes	F-112	74,600	92,300	20
Forged in electrice furnace at 1940 degrees and cooled in ashes as previously described	F-65	66,300	82,400	24½
	F-66	68,160	85,440	23½
	F-67	65,700	83,000	25
	F-68	63,700	84,000	25
	F-69	70,150	82,500	25
	F-70	61,040	83,600	25
	F-71	59,000	82,600	23
	F-76	63,300	85,400	25

Six specimens were raised to a temperature of 1325 degrees F. in the electric furnace, the temperature remaining at 1325 degrees for forty-five minutes, current was then shut off and specimen and furnace were allowed to cool to 200 degrees. Time required for this drop in temperature was forty-four (44) hours:

No.	Elastic Limit	Tensile Strength	Elongation Per Cent
R-38	58,250	87,350	29
R-39	59,050	86,900	29
R-40	59,650	86,650	29½
R-41	59,450	87,350	29
R-42	59,350	87,600	30
R-43	58,900	86,900	30

A series of tests were made in which the cooling took place in two operations. In this series all specimens were heated for forging in an oil furnace. They were heat treated for about one hour in the electric furnace and then cooled in ashes.

No.	Cooled with Furnace		Cooled in Ashes	Elastic Limit	Tensile Strength	Elongation Per Cent
	From	To	From			
R-26	1450	1100	1100	88,600	100,850	21
R-27	1450	1000	1000	84,500	91,350	23½
R-28	1350	Ash Cooling	Omitted	79,650	90,900	26½
R-29	1350	" "	"	82,200	90,850	27
F-15	Furnace Cool	Omitted	1600	53,680	101,440	20½
F-16	" "	"	1600	70,240	104,720	20½
F-17	1600	1500	1500	52,960	104,640	21
F-18	1600	1500	1500	69,440	106,720	21
F-19	1600	1450	1450	68,080	104,960	19

No.	Cooled with Furnace		Cooled in Ashes	Elastic Limit	Tensile Strength	Elongation Per Cent
	From	To	From			
F-20	1600	1450	1450	68,320	106,960	21
F-21	1600	1400	1400	78,400	109,600	21
F-22	1600	1400	1400	78,120	105,760	20½
F-23	1600	1350	1350	70,480	102,320	20
F-24	1600	1350	1350	69,040	107,200	21
F-25	1600	1300	1300	67,760	104,000	21
F-26	1600	1300	1300	66,720	105,200	22½
F-27	1600	1250	1250	78,600	106,400	21
F-28	1600	1250	1250	77,360	112,720	21
F-29	1600	1200	1200	69,280	105,200	20½
F-30	1600	1200	1200	20,240	108,000	20½
F-31	1450	1100	1100	76,240	105,600	22
F-32	1450	1100	1100	78,400	112,000	22
F-39	1450	240	240	63,200	90,800	26
F-40	1450	240	240	63,360	92,080	25½
F-33	1450	1000	1000	59,840	92,720	28
F-34	1450	1000	1000	60,800	90,400	25

Fourteen (14) specimens were forged from the electric furnace at 1940 degrees and cooled in ashes from 1275 degrees:

No.	Elastic Limit	Tensile Strength	Elongation Per Cent
F-72	65,150	92,000	23
F-73	75,800	95,700	20
F-74	65,000	91,600	20
F-75	69,500	91,500	23½
F-77	72,800	91,500	23
F-78	.....	90,000	23
F-79	.....	94,000	23
F-80	69,000	91,700	22
R-32	88,000	95,850	27½
R-33	70,150	94,400	28
R-34	70,900	93,000	29
R-35	73,500	91,600	28½
R-36	67,900	92,750	29
R-37	64,750	92,500	27

Six specimens forged in oil furnace at 1900 to 2000 degrees and heat treated for one hour gave the following results:

No.	Treat. Temp.	Elastic Limit	Tensile Strength	Elongation Per Cent
F-47	1275	68,640	104,000	25½
F-55	1275	66,960	102,080	26
F-56	1275	.....	109,360	24½
F-48	1300	74,560	99,040	20
F-57	1300	72,480	105,200	22
F-58	1300	71,360	106,440	19½

A comparison of the effect of quenching in oil and cooling in air is shown below:

OIL QUENCHING.

Treatment Temperature	Elastic Limit	Tensile Strength	Elongation Per Cent
1151 degrees	93,450	104,750	22
1251 degrees	94,000	104,450	20½
1316 degrees	89,050	105,300	22½

AIR COOLING.

1106 degrees	97,550	103,800	19½
1211 degrees	94,350	105,000	21
1261 degrees	94,700	106,100	20

Twelve specimens listed in table below were forged in an oil furnace at 1900 to 2000 degrees and cooled in air to room temperature. Heated to normalizing temperature in oil furnace cooled in air to 1250 degrees, placed in electric furnace and cooled. Estimate of temperature of specimen as it cooled in the air was made by comparison of its color with that of the interior of the furnace which was maintained at 1250 degrees:

No.	Normalizing Temperature	Elastic Limit	Tensile Strength	Elongation Per Cent
F-7	1300 to 1250	59,360	94,720	26
F-2	1350 to 1250	59,040	97,920	25
F-9	1400 to 1250	58,080	90,080	23
F-10	1450 to 1250	59,040	87,440	25
F-11	1550 to 1250	60,960	89,680	23
F-12	1610 to 1250	63,840	93,440	24½
R-18	1300	64,200	90,400	27
R-19	1350	70,600	91,150	28
R-20	1400	70,950	91,350	27
R-21	1450	70,900	92,060	27
R-22	1550	72,100	92,900	25
R-23	1610	73,550	93,450	23½

Several specimens were treated in the gas furnace allowed to cool, heated a second time quenched in oil, heated a third time and cooled with the furnace. This multi-stage treatment produced material as indicated below:

No.	Treatment Temperature	Quenching Temperature	Temperature at Start of Final Cooling in Furnace	Elastic Limit	Tensile Strength	Elongation Per Cent
R-4	1306-(in air)	1381	970	.....	155,000	13
R-5	1386- "	1441	1070	.....	142,859	17
R-VI	1600-(in furn.)	1520	1250	67,450	85,350	30
R-LV	1600- "	1520	1250	75,800	88,500	27
R-IV	1600- "	1520	1250	71,900	89,750	28
R-25	1600-(in air)	1520	1100	120,000	122,200	20
R-24	1600- "	1520	1100	.....	124,000	19

Six specimens were treated in the electric furnace partially cooled with the furnace and finally cooled in the air.

No.	Furnace Cooled	Elastic Limit	Tensile Strength	Elongation Per Cent
F-50	1350 to 910	64,000	91,760	27½
F-61	1350 to 910	65,680	92,000	27½
F-62	1350 to 910	73,440	93,120	23½
F-51	1325 to 400	.....	104,720	26½
F-63	1325 to 400	64,640	97,440	26
F-64	.....	68,720	91,840	26

In the following table the material tested was taken from the final blade forging and heat treated as indicated at 1325 degrees. All treatment took place in the electric furnace:

	No.	E. L.	T. S.	Per Cent Elongation		Scleros Read.
				1.5 in.	1.2	
100 Buckets treated 3 hours piled in box and packed in asbestos	B-1	72,600	101,760	20.8	25.7	
25 Buckets treated 3 hours piled in box not packed	B-2	58,200	96,800	25.3	.....	25
	B-3	58,200	95,000	27.3	.....	24-25
	B-4	66,100	96,700	26.7	.....	25
	B-5	60,700	96,000	24.0	.....	23-24
	B-6	68,600	97,000	25.0	.....	25
25 Buckets treated 1 hour piled in pan packed in asbestos	B-7	60,300	91,000	26.	28.3	...
	B-8	57,000	92,200	25.4	30.	...
	B-9	64,200	85,000	28.	33.4	...
	B-10	61,200	93,600	25.4	28.4	...
	B-11	57,500	92,200	28.	33.4	...
	B-12	63,500	85,500	27.3	33.4	...
	B-13	62,500	94,000	25.4	30.	...
	B-14	63,500	89,500	27.3	30.9	...
	B-15	63,400	92,300	26.	30.	...
	B-16	66,600	90,000	26.	30.	25
	B-17	61,000	81,900	29.	35.	25
	B-18	55,400	94,000	25.	30.	26
25 Buckets treated 1 hour distributed in box, cooled on bed of ashes in air	B-19	65,150	98,600	28.	30.8	25-26
	B-20	63,300	98,500	25.4	28.5	24-25
	B-21	68,000	97,000	26.6	29.2	23-24
	B-22	72,000	97,900	24.	27.7	24-25
	B-23	68,000	93,800	23.4	26.9	24-25
	B-24	64,100	96,400	25.4	27.7	23-24
	B-25	63,100	93,700	26.5	29.2	23-24

FORGING THE BLADES.

The material from which the blades under consideration are forged is 3½ percent nickel steel in bars 1 inch × ⅞ inch section. The mill scale is removed by pickling. Any scale remaining on the bar after the pickling is removed by an emery wheel.

The bars are then introduced into the furnace, the temperature of which is maintained at 1950 degrees. At the first heat the material is "Broken down" in the dies under the drop hammer into the blank form Figure 6. The blank is again heated to 1950 degrees and the final die forming takes place. After the fins are trimmed off the forging is again placed under the hammer (without reheating), and one blow is struck for the purpose of freeing the blade of scale and dirt.

Two methods of forging were tried; first, the method as described; and second, the blade was brought down to final dimensions in two heats after the breakdown of the blank. The additional heating and forging apparently produced no improvement in the material. The surface of the finished product appeared to be more scaly when the extra heating was employed.

As a test of quality of the material produced by the two methods of forging, the blades were placed in a vise and bent backward with a heavy lever. Careful note was made of the angle to which the forging was bent when the first sign of fracture appeared at the steam edge of the blade.

Numerous bending tests as described seemed to indicate that the quality of material was not improved by additional heating and forging. On the basis of this conclusion, it was decided to forge the blades in two heats only.

With the information gained from the foregoing series of experiments the following method of procedure has been adopted for the production of nickel steel blading.

Forge in two heats in the electric furnace at 1940 degrees F.

Treat for one hour at 1325 degrees F. in electric furnace closed tightly to exclude air.

Pack in asbestos and cool to about 850–900 degrees F., from which temperature material may be allowed to cool to room temperature in the air.

U.S.S. *MILWAUKEE.*

DESCRIPTION AND OFFICIAL TRIALS.

By Lieut.-Comdr. J. T. Alexander, U.S.N., Member.
Senior Engineer Officer.

The U.S.S. *Milwaukee* was one of the ten scout cruisers authorized by Act of Congress 29 August, 1916. A contract signed 27 August, 1917, covered the building of three of the scouts, the *Omaha, Milwaukee* and *Cincinnati,* by the Seattle Dry Dock and Construction Co. The building costs of each of the three vessels was $8,250,000.00 on the cost plus basis fee. The *Milwaukee* was the second vessel of the group completed under the contract.

Delays incident to the World War and reorganization of Seattle Corporation under the Todd Ship Building Corporation caused a modification of the original contract.

On 21 February, 1919, a supplementary contract was signed by the Todd Dry Dock and Construction Corporation of Tacoma, Washington, which Company took over the plans and such material as had been assembled under the first contract.

The keel of the U.S.S. *Milwaukee* was laid on 28 December, 1918. Work discontinued during the War and suspension of first contract delayed launching until 24 March, 1921. The vessel was christened by Mrs. Rudolph Fiel, Jr., of Milwaukee, Wisconsin. Conforming to the usual launching procedure at the Todd plant, the *Milwaukee* was launched bow first.

Construction was delayed several times due to lack of appropriations and it was not until 17 April, 1923, that the first dock trials were held. The builders' preliminary trials at 25 knots were held on 22 May, 1923. The official preliminary trials were held 1 June, 1923.

The U.S.S. *Omaha* having been designated to conduct the full series of trials specified by the contract for one vessel of

the group, the preliminary official trials on the U.S.S. *Milwaukee* were as follows:

(*a*) Four hours—Full Power.

(*b*) Test of steering gear—Full speed ahead, 20 knots astern.

(*c*) Reversal of engines from full power ahead to 200 R.P.M. astern.

On 20 June, 1923, the *Milwaukee* was delivered to the Commandant, Navy Yard, Puget Sound, and was commissioned on that date.

The hull and machinery description of the U.S.S. *Omaha* which appeared in the May, 1924, issue of this JOURNAL covers the general details of the other two ships of the group. The only important difference lies in the generating plants. The *Milwaukee* and the *Cincinnati* each have four 100 K.W. General Electric turbo generators. The *Omaha* has two 50 K.W. and two 100 K.W. General Electric turbo generators.

SOME INTERESTING DETAILS.

SCOOPS.

At speeds above twelve knots a scoop arrangement is used. The circulating water pump is shut down slowly after speed through the water is attained. A balanced flap valve opens the main injection piping directly to the forward condenser head.

An indicator showing the setting of the flap valve is located on the operating platforms from which steam throttles of the main circulating pumps are operated.

VACUUM TRAPS, ETC.

Below each low pressure turbine is located a drain tank which may be kept cleared of water by two means. (*a*) A pump or (*b*) A Wilmon Vacuum Trap. The pump is used in port, the trap is used when there is vacuum on main condensers. The pump is a Worthington Blake $4\frac{1}{2} \times 8 \times 6$ vertical simplex.

The vacuum trap consists of bucket and cam which when moving uncovers ports connected to vacuum and atmosphere. The water is lifted to the main condenser by the suction of vacuum after which the ports are closed and the trap is ready for another cycle.

FORCED LUBRICATION SYSTEM.

Each main unit has an independent forced lubrication system consisting of two supply pumps, a sump tank and necessary piping. In the forward engine room, the gear cases were required to be set low enough for Nos. 1 and 4 shafts to be led under the after boilers. This arrangement reduced the head of flow for oil from the gear case returning to the sump and it was found necessary to install a motor driven centrifugal gear case pump in the system.

The lubricating oil strainers are fitted with magnets which have proved of value in clearing the system of ferrous particles.

In each system is installed a Winters low pressure alarm which operates an alarm bell on the control platform when for any reason oil pressure to bearings is reduced below a safe operating limit. A tell tale light showing the continuity of this circuit is located at the gauge boards.

In addition to supplying the main turbine bearings, thrusts, governor valve, and oil relay, the main lubrication is provided for the main feed pumps, condensate pumps and casing drain pumps.

Oil cooling is effected through coolers installed on the after machinery flat which can be drained by gravity to the sump tanks.

LUBRICATING OIL SUMP TANK.

Capacity, 650 gallons.

Connections:

3-inch filling line from purifiers, settling and storage tanks.

8-inch pump suction.

8-inch drain from turbine bearings.

¾-inch drain to bilge.
4-inch drain from governor gear.
1½-inch vent.
4-inch drain from relief valve.
⅜-inch drain from cooler vents.
1-inch float gauge line.

NO. 1 LUBRICATING OIL DISCHARGE STRAINER.

Type—duplex. Size 6 inches.
Size—cartridge, diameter 9½ inches, length 18½ inches.
Numbers of hole, 932, ⅝-inch diameter.
Area of holes, 285.93 square inches.
Strainer, diameter, 9½ inches; length, 19½ inches.
Material, 30 mesh, composition "B."
Clear opening—127.33 square inches.
Purification of oil may be done through separators while underway. There is one separator for each unit.

DE LAVAL OIL SEPARATOR.

Operated, electric motor, belt drive.
Capacity, 100 gallons per hour.
Manufactured by De Laval Separator Co.

OIL SETTLING TANKS.

No. 2, one in each engine room.
Capacity, 800 gallons.
Material, 3/16-inch, class "C" steel, two compartments fitted with steam coils.

OIL STORAGE TANKS.

No. 2, one in each engine room.
Capacity, 1040 gallons.
Material, 3/16-inch, class "C" steel.
Connections: 2-inch filling from deck connection.
2-inch drain to drain tank.
1-inch drain to bilge.
2-inch overflow.

The lubricating oil systems forward and aft are cross connected for transferring oil to any of the four systems.

CONTROL EQUIPMENT.

Cummings integrating counters with follow-up dials are installed on each control platform. No. 1 throttle platform normally is the leading shaft. Due to structural reasons Nos. 1 and 4 throttle controls are separated by the width of the engine room necessitating an extensive system of counter gear shafting. The counters show the R.P.M. of individual shafts, the average of port and starboard shafts, as well as the all shaft average.

There is one Cory DC transmitting generator geared to each shaft for 4 repeaters shaft revolution counter. There is one McNab counter geared to each shaft for emergency use.

The Cory step by step engine telegraph system is installed, indicating in each fire room. The after engine room telegraphs repeat back to forward engine room.

DETAIL OF NO. 1 MAIN SHAFT.

Length, 205 feet $10\frac{11}{32}$ inches.
External diameter $14\frac{1}{2}$ inches to $15\frac{1}{2}$ inches to 15 inches.
Internal diameter $9\frac{1}{8}$ inches.

DETAILS OF LINE BEARINGS.

No. 8.
Bearing base and cap, cast iron.
Liner, composition "G." Babbitt lined.
Size, $14\frac{3}{4}$ inches, plus .002-inch diameter.
Length, 20 inches.
Ring oiled.

MAIN FEED PUMPS.

There are two main feed pumps in each engine room of the following characteristics:

Type, Turbo Centrifugal.
Turbine, Sturtevant Special, C-12.

Steam 265 pounds.
Exhaust 10 pounds.
B.H.P. 205.
R.P.M. 3000.
Pump, Worthington two stage.
Capacity 600 gallons per minute, 35 pounds pressure.
Connections:

6-inch suction from F. & F. tank.
5-inch discharge to main feed line.
2½-inch relief valve.
1-inch discharge to turbine gland.

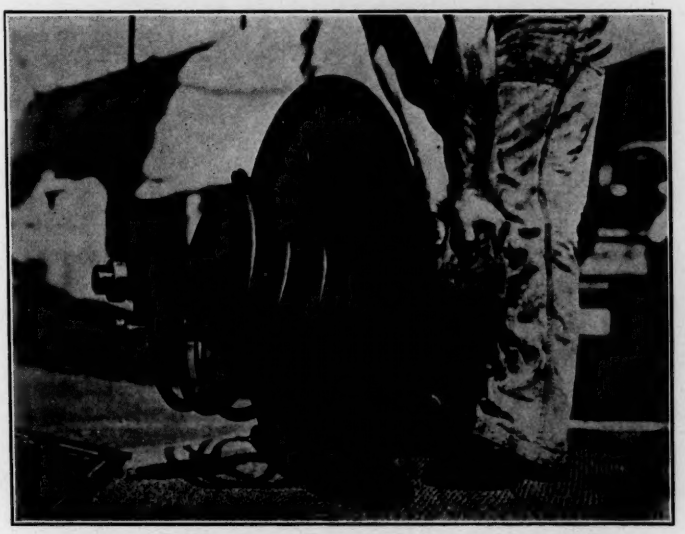
Each pump is fitted with an Ideal U 2½-inch governor control valve.

FEED AND FILTER TANK DATA.

Capacity, 3000 gallons. Material, ¼-inch class "C" steel.
Strainers, 3/16-inch class "C" steel. Gauge glasses ¾-inch diameter, 25 inches long.
Filters, Loofa sponges held by corrugated wire mesh support.
Connections:

2-inch distiller fresh water discharge.
10-inch condensate inlet.
4½-inch auxiliary air pump discharge.
4½-inch combined, 3½-inch reserve feed discharge.
2½-inch L.P. drains.
1½-inch relief valve discharge from gland control valve.
8½-inch main feed suction.
1½-inch drain to bilge.
3-inch vents from filter chamber.
5-inch overflow to reserve bottoms B-2 for'd, and B-4 aft.
3-inch main condenser suction.
4-inch H.P. trap drains.
8½-inch auxiliary feed suction.
5½-inch drain from feed water heaters.

A View of Boiler Room No. 3, Facing to Starboard.



Atomizer and Register Front, Showing Coiled Tube Type of Flexible Connection.

The following tables show in general the operating conditions at intermediate powers.

U.S.S. MILWAUKEE

Summary of Four Hour 20 Knot Steaming Trial.
7 September, 1923. 8 - 12 AM.

Unit.	No. 1	No. 2	No. 3	No. 4
Main steam, lbs. gauge	250.4	246.8	246	250.4
H.P. chest, lbs. absolute	167.3	172	153	152
I.P. chest, lbs. absolute	74	75	75	78
By pass	0	0	0	0
L.P. chest, vacuum, inches	24	20	25.6	27.7
Vacuum gauge, inches	28.1	28	29	28.7
Vacuum by Hg. column, inches	27.4	27.5	28	28
Barometer, inches	29.98	29.98	29.96	29.98
Exhaust temp. degrees F.	104.1	105.2	107	92
Nozzles used	5	5	5	5
Condensate, degrees F.	85	89	88	81
Injection, degrees F.	66	66	66	66
Discharge, degrees F.	85	88	91	86
Ejectors used, No.	A and B	A and B	A and B	A and B
Steam to ejectors, lbs. gauge	140	145	140	145
Auxiliary exhaust, lbs. gauge	10	10	10	10
Where used	--	LPT	LPT	--
Oil to coolers, degrees F.	109	110	110	109
Oil from coolers, degrees F.	102	102	104	102
H.P. thrust, degrees F.	106	112	108	104
Main thrust, degrees F.	107	109	107	107
Warmest bearing temp. degrees F.	124	142	125	121
Warmest bearing	HP Fwd	HP Fwd	HP Fwd	HP Fwd
Feed tank, degrees, F.	141	140	140	141
Eng. room temp. degrees F.	122	121	121	122
R. P. M.	193.6	198.3	189.3	188.5
Shaft horsepower	4,139.3	4,163.5	3,424.2	3,813.8
Average R. P. M. 4 hours		192.4		
Total shaft horsepower		14,540.8		

Boiler Data

In use	Br.No.2	Br.No.3
Steam, lbs. gauge	251	250
Oil temp. degrees F.	176	170
Air pressure, inches water	5.1	5.4
Feed water, degrees F.	226	230
Number burners	9	9
Oil to meters, degrees F.	68	72
Pyrometer, degrees F.		
Highest	880	675
Lowest	640	500
Blowers, R. P. M.	1,000	1,000
CO_2 average	10.3	10.3
F.R. temp. degrees F.	134	132

U.S.S. MILWAUKEE

Summary of Four Hour 25 Knot Steaming Trial.
7 September, 1923. 1 - 5 PM.
(Readings Show Average For Four Hours.)

Unit.	No. 1	No. 2	No. 3	No. 4
Main steam, lbs. gauge	250	248	249	250
H.P. chest, lbs. absolute	196	242	226	224
I.P. chest, lbs. absolute	21	16.8	20	16.5
By pass	20	10	21	16
L.P. chest, vacuum, inches	14	20	20	15
Vacuum gauge, inches	28.1	27.8	29	28.5
Vacuum by Hg. column, inches	27.7	27.5	28	28.2
Barometer, inches	29.85	29.85	29.85	29.85
Exhaust temp. degrees F.	104	111	104	97
Nozzles used	5&7 by pass	5&7 by pass	5&7 by pass	5&7 by pass
Condensate, degrees F.	90	94	92	90
Injection, degrees F.	67	67	67	67
Discharge, degrees F.	90	93	90	89
Ejectors used, No.	2	2	2	2
Steam to ejectors, lbs. gauge	140	138	140	145
Auxiliary exhaust, lbs. gauge	8.8	9	9	9
Where used	LPT	LPT	---	---
Oil to coolers, degrees F.	123	123	123	113
H.P. thrust, degrees F.	117	121	120	120
Main thrust, degrees F.	118	120	120	118
Warmest bearing	HP Fwd	HP Fwd	HP Fwd	HP Fwd
Warmest bearing temp. degrees F.	140	154	137	140
Feed tank, degrees F.	134	127	127	134
Eng. room temp. degrees F.	119	121	121	119
R. P. M.	239.8	238.4	238.7	239.3
Shaft horsepower	7,567.6	7,534.9	6,276.0	7,156.3
Average R. P. M.		239.1		
Total shaft horsepower		28,534.8		

Boiler Data

In use	Br.No.2	Br.No.3
Steam, lbs. gauge	252	255
Oil temp. degrees F.	170	170
Oil pressure, lbs. gauge	185	160
Air pressure, in. water	6.1	7
Feed water, degrees F.	220	218
Number burners	15	15
Oil to meters, degrees F.	68	69
Pyrometer, degrees F.		
Highest	880	880
Lowest	760	730
Blowers, R. P. M.	1350	1300
CO_2 average	10	10
F.R. temp. degrees F.	108	100

OFFICIAL TRIAL DATA.

Duration, hours	4
R. P. M. mean	380.5
Knots corresponding	34.7
Shaft horsepower	90,060
Number of boilers	12

Steam pressure (gauge).		*Air pressure (In. water).*
No. 1 F. R.	254	7.2
No. 2 F. R.	257	6.6
No. 3 F. R.	258	6.9
No. 4 F. R.	269	6.7

Vacuum.	*No. 1 Unit.*	*No. 2 Unit.*	*No. 3 Unit.*	*No. 4 Unit.*
Inches (referred)	27.8	27.6	28.2	27.9
Temperature degrees F. (Injection)	47	48	47	47
Steam to H. P. throttle	232	230	245	250

After a month at the Navy Yard fitting out with equipment and completing the Sonic Depth finder installation the *Milwaukee* sailed for a cruise into the South Seas for the purposes of testing the installation and of navigational research. The itinerary included several isolated atolls, the exact location of which had never been accurately charted. A search for certain submerged shoals of whose existence there was doubt was made with the Sonic Depth finder. A line of soundings exploring the ocean depths to the southward of Hawaii was also completed.

It is interesting to note that the power plants of this class designed for 90,000 S.H.P. have exceeded their contract power. At full power, the plant output equals the 1921 average daily peak electrical power consumed by the city of Los Angeles. Including ships auxiliaries but excluding shaft alleys, the power plant is contained in a space of 10,400 square feet and a volume of 228,000 cubic feet.

To indicate the performance of the sixteen turbines, eight reduction gears, six condensers, seventy-two pumps and other appurtenances requires the use of one hundred sixty-one thermometers, four hundred forty-eight gauges and four mercury columns.

During the cruise, the itinerary of which is given below, the ship steamed by engine revolutions a distance of 20,697.3 miles.

Left.		*Arrived.*		*Miles Steamed.*
Puget Sound, Wash.	21 July.	Honolulu, Hawaii.	30 July, 1923.	2,742
Honolulu, Hawaii.	2 August.	Pago Pago, Samoa.	8 August, 1923.	2,305
Pago Pago, Samoa.	10 August.	Suva, Fiji.	13 August, 1923.	672
Suva, Fiji.	16 August.	Sydney, Australia, N. S. W.	22 August, 1923.	1,775
Sydney, Australia.	6 September.	Brisbane, Australia.	8 September, 1923.	636
Brisbane, Australia.	12 September.	Noumea, New Caledonia.	15 September, 1923.	822
Noumea, N. C.	18 September.	Shortland, Har. S. I.	22 September, 1923.	1,622
Shortland, Har. S. I.	24 September.	Bougainville Kieta, S. I.	24 September, 1923.	78
Bougainville, S. I.	25 September.	Truk, Caroline Is.	28 September, 1923.	916
Truk, C. I.	30 September.	Hall, Caroline Is.	30 September, 1923.	68
Hall, C. I.	3 October.	Rabaul, New Britain.	6 October, 1923.	998
Rabaul, N. B.	11 October.	Mortlock, Caroline Is.	13 October, 1923.	726
Mortlock Is.	15 October.	Eniwetok, Marshall Is.	18 October, 1923.	657
Eniwetok, M. I.	19 October.	Rongelab, Marshall Is.	20 October, 1923.	285
Rongelab, M. I.	22 October.	Pearl Harbor, Hawaii (via Taongi, M. I.).	29 October, 1923.	2,608
Pearl Harbor, T. H.	8 November.	Hilo, Hawaii.	13 November, 1923.	1,475
Hilo, Hawaii.	14 November.	Puget Sound, Wash.	22 November, 1923.	2,692

NOTES.

BAGNULO OIL ENGINE.*

Scarcity of gasoline and its consequent high price as compared with the pre-war period awakened among its users the desire to free themselves of this heavy burden and to search for a light weight engine using heavier oils. Although a standard type of gasoline engine equipped with a suitable vaporizer will burn oils somewhat heavier than gasoline with satisfactory fuel consumption, yet its operation is more troublesome and maintenance cost higher. On the other hand, an engine of the Diesel or Semi-Diesel type has its high fuel economy offset by heavier weight and the comparatively slow rotative speed possible.

The persistent efforts of Alberto Bagnulo to combine light weight with high rotative speed in small cylinder dimensions finally brought him success after long years of experimenting. The Bagnulo Oil Engine is a high speed explosion motor with hot bulb ignition, but the fuel instead of being injected into the bulb by the pressure of the pump reaches it during the early part of the suction stroke, hence the fuel has ample time during the suction and compression strokes to be vaporized by the hot walls of the bulb and automatically ignites with considerable increase in pressure as soon as the piston reaches the upper dead center.

To the side of the working cylinder *"a,"* Fig. 1, is fastened a hot bulb *"d"* of comparatively small size (about 22 per cent of the piston displacement), which must be heated up before starting the engine. Over the hot bulb and separated from it by the ribbed nozzle piece *"b"* is a small spring loaded valve *"c"* which holds the fuel coming to it by gravity. When the piston is going down, creating in the cylinder a certain difference in pressure, this valve opens and admits the fuel together with a small amount of added air into the upper cone of nozzle *"b"* and from there in small drops into the hot bulb *"d."* This nozzle *"b"* is a very vital part—it protects the valve from the high temperature of the combustion chamber and prevents vaporization of the fuel on top of it.

The fuel upon reaching the combustion chamber, vaporizes during the suction stroke by absorbing the heat of the walls of the bulb, can not burn, however, because the hot bulb is filled with products of combustion from the preceding cycle and the slight amount of air entering it with the fuel is insufficient. The suction of the liquid fuel occurs during the first 20 per cent or 25 per cent of the downward stroke of the piston, after that, *i.e.* about 50 degrees below the top center, the mechanically operated suction valve opens and admits a fresh air charge into the cylinder while the fuel valve closes by the action of the spring. On the following compression stroke air with sufficient oxygen to burn all of the fuel charge is forced into the hot bulb, and upon entering it is thoroughly mixed with the vaporized fuel due to turbulence created, insuring successful combustion. Just before the piston reaches the top dead center the heat of the compression combined with the heat from the red hot walls of the bulb causes the fuel charge to ignite automatically. The necessary compression pressure according to the fuel used is from 110 to 150 pounds per square inch. The

*An article by L. Hausfelder in the "Zeitschrift d. V. D. I.", No. 18, of 3 March, 1924, translated by E. C. Magdeburger.

mixture burns quickly as is shown by the sudden rise in pressure, similar to that of the explosion type of engine. The high resultant pressure of the combustion chamber (about 375 pounds per square inch) spreads through the wide port connecting the bulb into the cylinder and the small remainder of the air charge on top of the piston is thereby heated up. This tends to reduce the temperature of combustion but the heat absorbed is turned into mechanical work during the expansion stroke. The mean temperature of the expansion stroke of this engine is lower than of other hot bulb engines, this being demonstrated by a smaller amount of heat carried away by the cooling water and by a comparatively low exhaust temperature. The products of combustion leave the cylinder in the usual manner, through an exhaust in the cylinder head.

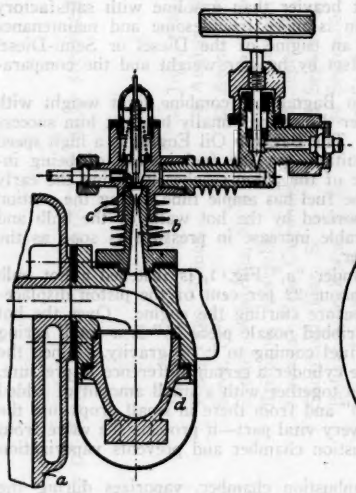


FIG. 1.—HOT BULB AND FUEL VALVE OF THE BAGNULO ENGINE.

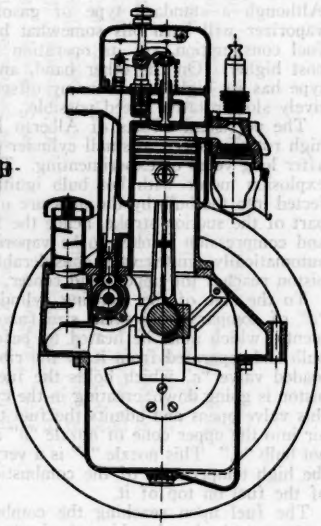


FIG. 2.—CROSS-SECTION OF A 20 H.P. TWO-CYLINDER ENGINE.

The working cycle of the Bagnulo engine is thermodynamically very efficient because the vaporization of the fuel charge is automatic, the mixing of the oil vapor with the necessary air for combustion occurs just prior to the working stroke and the combustion takes place with approximately constant volume at the top dead center. The results are a comparatively low consumption of combustion air, high piston speed and low fuel consumption.

Tests have shown that the mean fuel consumption of an engine of 35 horsepower nominal rating using ordinary tar oil from brown coal distillation amounts to only .506 pound per horsepower hour corresponding to a thermodynamical efficiency of 30 per cent. By increasing the rotative speed

from 1200 R.P.M. to 1650 R.P.M., and that is possible without any difficulty whatever, the Bagnulo engine compares with the best heavy duty gasoline truck engines with only a slight increase in weight. A drawback as compared with the gasoline engine is, of course, the necessity of preheating the bulb prior to starting the engine. This can be done either by heating with a blowtorch, ignition capsules or electrically, the latter especially suits truck service conditions.

The construction of the engine differs only very little from a modern automobile engine (See Figs. 2 and 3). Liberally dimensioned valves

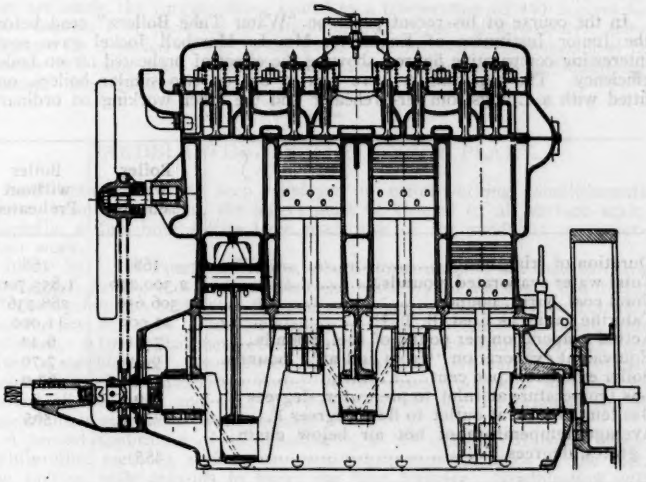


FIG. 3.—SECTION OF A 40 H.P. FOUR-CYLINDER ENGINE.

arranged in a separate cylinder head are actuated by push rods and rocker arms from a camshaft in the crankcase which completely encloses all of the driving gears. The pistons are of light aluminum alloy and the crankshaft runs in liberally dimensioned main bearings. Lubricating oil under pressure is circulated by a rotary pump. The cooling water for engines of larger size is circulated by a centrifugal pump whereas engines below 20 horsepower depend on thermosyphon circulation. To assure equality of load carried by each cylinder a distributor plate is driven from the forward end of the camshaft with pipe connections leading to each of the four fuel valves about the hot bulbs. The speed of the engine is regulated by a throttle; stationary engines are furnished with a centrifugal governor operating a spring loaded throttle valve in the fuel pipe leading to the distributor.

In designing the engine, the requirements of mass production were not overlooked—all engines of the same cylinder bore have perfectly interchangeable pistons, connecting rods, bearing shells, hot bulbs, valves, etc., thus the production costs are comparatively low.

The Bagnulo engine is suitable for various applications, while the small one and two cylinder models were designed for driving centrifugal pumps

or generators either in the stationary or portable units, the larger engines of 40 to 60 horsepower may be used in tractors, motor driven rail cars and trucks. Spa Automobile Company of Turin, Italy, has made some extensive and successful tests with truck installations. Lately, several Bagnulo engines of 40 horsepower normal rating were designed and built for aviation purposes and installed in airplanes of an Italian Army flying school.

BOILER EFFICIENCY WITH PRE-HEATED AIR.

In the course of his recent paper on "Water Tube Boilers," read before the Junior Institution of Engineers, Mr. L. Marshall Jockel gave some interesting comparative figures, showing the effect of preheated air on boiler efficiency. The experiments were carried out on two similar boilers, one fitted with a Ljungström air-preheater and the other working on ordinary

	Boiler with Preheater	Boiler without Preheater
Duration of trial, hours	168	168
Total water evaporated, pounds	2,300,240	1,853,700
Total coal burnt, pounds	306,656	288,736
Calorific value, as fired, B. T. U.	11,000	11,000
Actual evaporation per pound of fuel, pounds	7.50	6.42
Equivalent evaporation "from and at", pounds	9.0	7.70
Boiler efficiency, per cent	79.4	67.9
Gas temperature at inlet to preheater, degrees F.	610	...
Gas temperature at outlet to flue, degrees F.	250	565
Average temperature of hot air below chain grates, degrees F.	455	...

cold air with natural draft. The tests each lasted for a week, and the boilers were operating during that time under ordinary conditions of service, a fact which renders the results more significant. It will be noted that the effect of the pre-heater was to bring about a saving of about 13.6 per cent in the fuel, after taking into account the power absorbed by the fans in the Ljungström air heater. Neither boiler was provided with an economizer.—"Engineering," May 9, 1924.

ALUMINIUM-ALLOY CONNECTING RODS.

The use of aluminium alloys for the construction of the pistons of heavy-oil engines was recommended by Mr. Beeman in the paper which he read at the recent meetings of the Institution of Naval Architects. It is not, however, generally known that successful attempts have been made to use these alloys for the construction of connecting rods, although so far they have only been applied to comparatively small engines. In a paper read before the Institution of Automobile Engineers, Mr. Leslie Aitchison stated that those engineers who had used light alloys for the construction of connecting rods had found the experiment to be a very remunerative one, and

inadvertently they have demonstrated that the use of these alloys for this purpose is almost easier than it looks. For the manufacture of connecting rods in which high strength and high ductility are required, cast aluminium alloys are not particularly suitable, as a strength exceeding 12 tons per square inch cannot easily be obtained, and this is associated with poor ductility. On the other hand, the best commercial wrought alloys give a maximum stress of about 26 tons per square inch. The most suitable alloy available for this purpose is Duralumin, and drop forgings are used for the manufacture of the connecting rods. These, it is stated, can be produced without difficulty. They are heat treated at the same time as the drop forgings are made, the forging being heated to a temperature of 480 degrees C. (896 degrees F.), quenched in water and then "aged" at atmospheric temperature for a period of five to six days. The forging is then machined in exactly the same way as for the cast alloy.—"Shipbuilding and Shipping Record," May 29, 1924.

SANDBLASTING IN THE POWER PLANT.

Sandblasting has long been employed in metal-working establishments where, before lacquering, the object must be cleaned of all surface scale. Recently, a few bold spirits have made use of the sandblast in power-plant work.

In the St. Louis Pumping Station, where steam turbines are used to drive centrifugal pumps, it was found that the efficiency of the units had fallen off twenty-five per cent from the guarantee figures. Investigation revealed that the first five rows of turbine blading were almost completely closed with sediment. After replacement of a few rows the entire blading surface was given a sandblasting. As reported by Leonard A. Day before the Annual Convention of the American Water Works Association, this blasting removed all the scale and upon resumption of service the original steam-consumption guarantees were equaled.

A second application of sandblasting is in the cleaning of boiler tubes. While other methods, such as the wire brush, removes much of the soot, the surface scale remains to lower the heat transfer. Sandblasting will remove all deposits down to the bare tube and may be used both on fire and water tubes.—"Power," June 3, 1924.

RECONNECTING DIRECT-CURRENT ARMATURES—TYPES OF ARMATURE COILS.

By A. C. Roe.

The armatures in modern direct-current motors and generators are mostly wound with diamond-shaped two-layer pulled-type coils, although some of the early types of armatures used mold-wound coils of different shapes. Fig. 1 shows a type of wire coil that is wound on a mold to shape and uses one type range of motors. This coil is what is known as half diamond and half involute. The figure shows a plan view; that is, looking down on the coil. The longest side A is the top half and the short side B the bottom half. The coils are so shaped as to allow them to nest into a two-layer winding. This type of coil is wound in two sections, which are then hot-pressed together to form a group of two coils, each consisting of two turns of two No. 8 double cotton-covered wires in parallel, making four leads to a side as shown. The leads are on the bottom of the coil. The top leads are brought out between the coils to the commutator, and the

bottom leads bend down under the winding out of the way. This type of coil requires an expensive mold, as the coils are wound to the exact and final shape. As there are two single coils taped together, for an armature having 47 slots and 93 commutator bars there would have to be 94 single coils. These would then be assembled and pressed together. A 0.005-inch or 0.003-inch paper cell is glued to the slot section of the coils while winding. The cotton covering on the leads is also put on while winding and fastened under the paper cells. After being pressed, the coils are dipped in an insulating varnish and baked, after which 1½ turns of treated-cloth wrapper is put on the slot section and the whole coil taped with one layer of 0.007-inch thick by ¾-inch wide cotton tape. This tape is half overlapped on the ends and butted on the cell section. After being taped, the coil is again dipped in an insulating varnish and baked.

Fig. 2 shows another type of mold-wound coil. This was used on a type range of direct-current machines and requires less room at the end of the armature than the coil, Fig. 1. Fig. 2 indicates the way the coils nest together. This type of coil is wound with the leads on top, which requires that the bottom leads be bent down and the top leads come out over the ends. This coil requires the same expensive mold and the expenditure of the same amount of labor as the type Fig. 1.

The latest type is the diamond pulled coil, Fig. 5. This coil is wound on a shuttle and then pulled or spread to shape either by hand or in a pulling machine. Fig. 7 shows the type of shuttle or form that the coil may be wound on, although a more elaborate one may be used in large shops. It consists of two pieces of lumber, one of which is mounted on a bolt, that may be used to support the shuttle in a lathe chuck when winding the coil. The center block B is just wide enough to take the number of wires that make the width of the coil. Fig. 3 shows a shuttle on a winding machine with a coil ready to be taken off. The shuttle Fig 7 may be arranged to be turned by hand as in Fig. 6. In large shops a pulling machine may be used to spread the coil to shape. With a little care a good job can be done by hand as indicated in Fig. 8. One side of the coil is gripped in a vise between two pieces of wood about ⅛ inch longer than the armature slots. Then by clamping two similar pieces on the opposite side, the coil is pulled to the desired diamond shape by hand as indicated at A in the figure.

MAKING SHUTTLE TO WIND COILS ON IS AN EASY JOB.

Making the shuttle to wind the coils on is a simple job that requires only one or two hours' work compared to a very complicated mold for the coils shown in Figs. 1 and 2. Another advantage of the diamond-shaped pulled coil is that in repair work the shuttles can be cut down for other jobs and there is not a stock of expensive molds on hand. The coil can also be wound complete with any number of wires in hand, thus saving considerable time. Fig. 5 shows the final shape of the pulled coils and how they nest together. The operations on making one type of diamond-shaped coils in the shop of one manufacturer are: After winding, the coils have a paper cell glued to the slot section, or they are tied so that the wires will hold together, then dipped in a good insulating varnish and baked, the varnish holding the wires together. The next operation is to pull the coils to shape, then insulate and dip again.

Another type of coil is that made of strap copper. This coil is made up from bare copper strap, which is first cut in proper lengths, then bent on edge into a hairpin shape and the bends annealed and formed to shape on a wooden or iron former. Fig. 4 shows a complete strap-copper coil, which consists of 5 coils insulated together. This coil is for a wave-wound armature since the leads to the commutator bend away from the center of the coil. Sometimes it is possible to shape this type of coil on the pulling

FIG. 1.—HALF-DIAMOND AND HALF-INVOLUTE TYPE OF COIL.

FIG. 3.—PULL-TYPE COIL ON WINDING SHUTTLE.

FIG. 4.—STRAP-COPPER COIL FOR WAVE WINDING.

FIG. 2.—SHOWS HOW TWO MOLD-WOUND COILS NEST TOGETHER.

FIG. 5.—TWO DIAMOND-SHAPED COILS NESTED TOGETHER.

machine. In repair work it is seldom that such coils have to be made since, if the insulation is destroyed, it is only a matter of reshaping and reinsulating the coils.

Wherever possible in making a change in a winding having coils of the types shown in Figs 1 and 2, they should be changed to a diamond-shaped

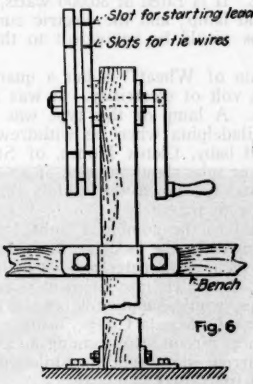


Fig. 6

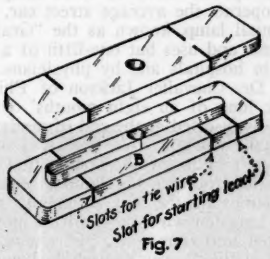


Fig. 7

FIGS. 6 AND 7.—SHUTTLE FOR WINDING PULL-TYPE DIAMOND-SHAPED COILS.

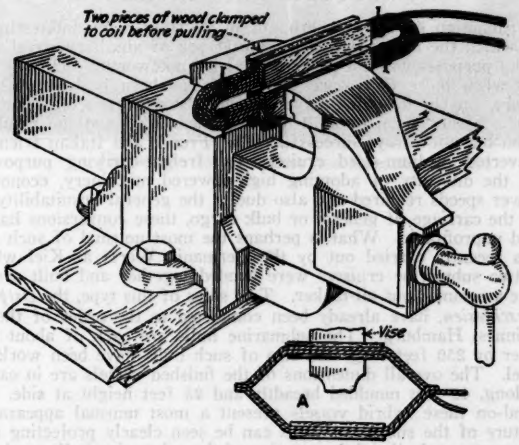


FIG. 8.—METHOD OF FORMING DIAMOND-SHAPED COILS.

coil that can be wound as indicated in Figs. 6 to 8, which will result in considerable saving and will give as good a job if done right.—"Power," May 27, 1924.

ELECTRIC LIGHT EXTREMES.

The smallest and the largest incandescent lamps in the world, one rated at about one-quarter candlepower and the other at about 100,000 candlepower, make an interesting display when shown side by side. The large lamp, with a bulb 12 inches in diameter and 18½ inches high, was developed primarily for motion-picture studio use. It is rated at 30,000 watts, or 1200 times larger than the average household lamp; and the electric current required to operate three of these lamps would be equivalent to the power used to operate the average street car.

The small lamp, known as the "Grain of Wheat," is but a quarter inch in diameter and uses but one-fifth of a volt of electricity. It was designed for use in hospitals and by physicians. A lamp of this type was recently used by Dr. Chevalier Jackson of Philadelphia when he withdrew a tack from the lung of an eight months' old baby, Cletus Moore, of St. Louis. The bulb is inserted at the end of a silver tube about the size of an ordinary lead pencil, which in this case was inserted down the child's throat and gave enough light for the doctor to locate the tack.

The light from the big lamp is equal to the combined light from 2400 electric lamps of the size commonly used in the home. The filament is made of tungsten wire one-tenth of an inch in diameter and 93 inches long, constructed into four coils. This wire, if drawn into filament wire of the size used in the 25-watt household lamps, would supply filaments for 55,000 such lamps. These lamps are classified as the Mazda C type, being gas filled, and are lighted from a 120-volt 250 ampère circuit. Consuming 30 kilowatts, the cost to operate such a lamp with current at 10 cents per kilowatt would be $3 per hour.—"Scientific American," June, 1924.

UNIQUE SUBMARINE CONVERSION.

The termination of the war brought in its train many interesting problems, of which the application of various types of auxiliary naval craft to commercial purposes was not perhaps the least noteworthy. History records occasions when more than once the sword has been beaten to form the ploughshare, but in diverting naval warcraft to the peaceful pursuits of commerce a higher form of skill has been demanded and the results have been quaint but not always successful. Our French and Italian friends have each converted medium-sized cruisers for freight-carrying purposes, but owing to the difficulty of adopting high-powered machinery, economically, to the lower speeds required and also due to the general unsuitability of the hulls for the carriage of general or bulk cargo, these conversions have been costly and unprofitable. What is perhaps the most unusual of such conversions was recently carried out by the Germania Werft at Kiel when the hulls of two submarine cruisers were bonded together and built around to form quite a commodious oil-tanker. Two ships of this type, the *Östpreussen* and *Oberschlesien*, have already been completed to the order of the A. G. Hugo Stinnes, Hamburg. The submarine hulls are each of about 20 feet in diameter by 250 feet long, and two of such hulls have been worked into each vessel. The overall dimensions of the finished vessels are in each case 290 feet long, 41 feet moulded breadth, and 25 feet height at side. When viewed end-on these hybrid vessels present a most unusual appearance, as the curvature of the submarine hulls can be seen clearly projecting at each side. The water and oil-tight properties of the submarine hulls render them quite suitable for their new service of oil carrying and the oil cargo is stowed not only within the two hulls but also in the holds above and between them. By the addition of a bow and a stern quite a tolerably ship-shape form has been developed. The vessels are propelled by the former submarine Diesel engines driving twin screws, and the reduced power of these units is

EXTREMES OF THE DAY IN ELECTRIC LAMPS.

700 horsepower each. All auxiliaries are operated electrically, and a small donkey boiler has been provided for heating the oil cargo and for steaming tanks. The results of both vessels on service have been highly satisfactory.—"Shipbuilding and Shipping Record," May 15, 1924.

LAUNCH OF A 4,500-TON FLOATING DOCK.

The Methods Adopted by Burgerhout's Engineering & Shipbuilding Company, Rotterdam, to Overcome Launchway and Restricted Water Difficulties.

When it is borne in mind that in launching operations very difficult problems frequently arise, it is greatly to the credit of shipbuilders that very few mishaps of a serious nature occur. Some time ago we published an article on the methods adopted to overcome the difficulties met with in launching a new fore end to the *Sydland*. Another interesting job was recently carried out by Burgerhout's Engineering & Shipbuilding Company at Rotterdam, when they launched a 4,500-ton floating dock built for the Sociedad de las Habas, Valparaiso. A short description of this dock and of its passage down the Meuse to the Waalhaven, Rotterdam, from the builders' works appeared in "Shipbuilding and Shipping Record," May 15.

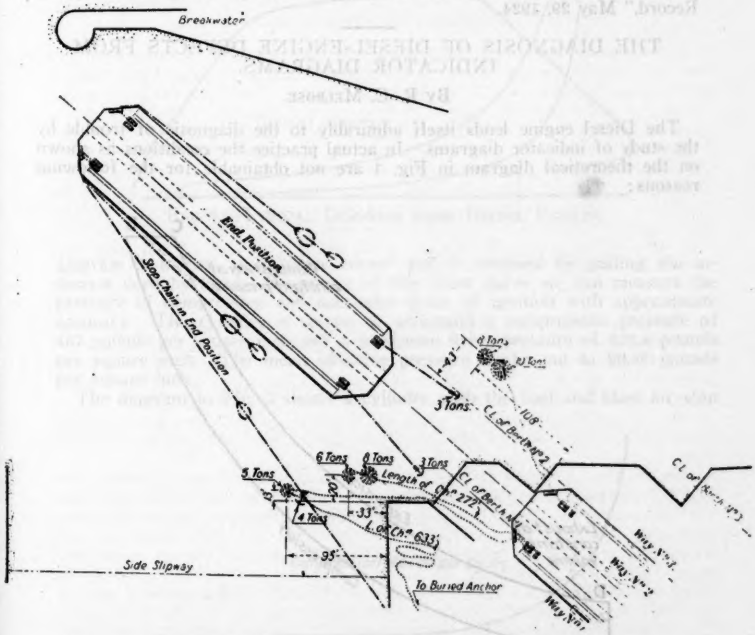


Diagram Showing Position of Launchways and the Arrangement and Weight of Drags.

From the adjacent diagram it will be noted that three ways were built under the dock, one under each wall and one under the longitudinal bulkhead adjacent to the center of the dock. The first difficulty to be overcome was due to the condition that ways Nos. 1 and 2 were approximately the same length, but way No. 3 was 65 feet shorter. Also way No. 2 extended for 24 feet farther than ways Nos. 1 and 3 at the fore end of the dock.

The following is a short description of the methods adopted to launch the structure: At the point where the dock had travelled half its own length and was ready to lift, it was arranged that ways Nos. 1 and 3 took the load, No. 2 sliding way being sloped, so that it did not make contact with No. 2 standing way until the point was reached where No. 3 sliding way left No. 3 standing way. At this point ways Nos. 1 and 2 received the full load of the dock. The position of way No. 2 prevented the dock from swinging, and in order to diminish the fore poppet pressure on way No. 3, ballast water was taken in the dock at the opposite end side-tank to an amount of 250 tons.

Special care was taken with the construction of ways Nos. 1 and 2 to withstand a fore poppet pressure of about 300 tons maximum that occurred.

Another point of interest was the restricted water into which the structure was launched. The diagram illustrates this, and shows the position of the dock before launching and also its position when pulled up; the positions of the anchors and drags are also shown.—"Shipbuilding and Shipping Record," May 29, 1924.

THE DIAGNOSIS OF DIESEL-ENGINE DEFECTS FROM INDICATOR DIAGRAMS.

By R. C. Melrose.

The Diesel engine lends itself admirably to the diagnosis of trouble by the study of indicator diagrams. In actual practice the conditions as shown on the theoretical diagram in Fig. 1 are not obtainable for the following reasons:

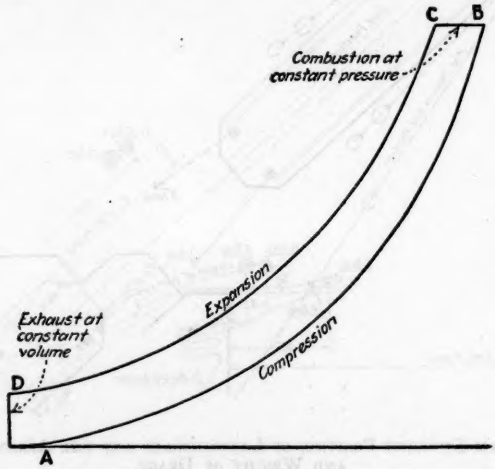


Fig. 1.—Theoretical Diesel Diagram.

1. The water circulating in the jacket, cylinder head, and piston absorb heat during compression and expansion, causing both curves to fall.
2. Particles of oil are still burning after the fuel valve is closed; the general tendency of this condition is to reduce the pressure during the combustion period and raise the expansion curve. This is called "after burning," and although some think the effect is beneficial as it increases the mean effective pressure, it is actually a disadvantage in that the fuel consumption per brake horsepower is increased, and carbon troubles occur.
3. The combination of oxygen, carbon, and hydrogen does not remain constant, consequently the expansion curve tends to flatten out. With the theoretical diagram a perfect gas is assumed, the specific heat of which is constant.
4. Mechanical defects such as leaking piston rings, exhaust valves, air inlet valves, fuel valves and air starting valves, etc.
5. The effect of high piston speed on volumetric and scavenging efficiencies.

DIAGRAMS FROM WORKING ENGINES.

Fig. 2 shows a diagram taken from a four-stroke-cycle engine and may be accepted as representing good practice. The curved line above the

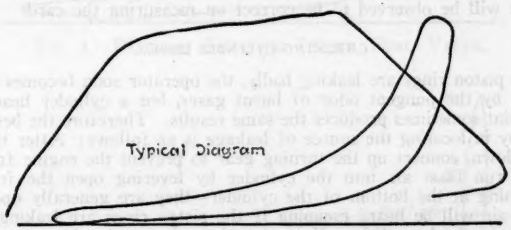


FIG. 2.—TYPICAL DIAGRAM FROM DIESEL ENGINE.

djagram is known as a "draw curve" and is obtained by pulling the indicator cord by hand. By means of this draw curve we can measure the pressure of compression and maximum point of ignition with approximate accuracy. The cylinder is shown to withstand a compression pressure of 467 pounds per square inch and a maximum firing pressure of 525.4 pounds per square inch. The mean effective pressure works out to 90.88 pounds per square inch.

The diagram in Fig. 3 shows a cylinder with the fuel and blast air shut

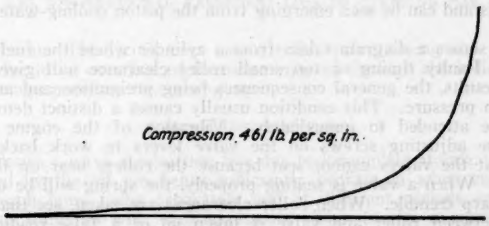


FIG. 3.—COMPRESSION DIAGRAM WITH FUEL CUT OUT.

off, and from it many defects can be deduced. Assuming that the piston rings are tight and that all valves are free from leakage, the expansion curve should cover the compression curve and both appear as one, as the difference due to the heat given up to the jacket cooling water will not show on such a small scale. If the cylinder shows reluctance to start firing when starting up from cold, as soon as the engine is under way the engineer should take a diagram with the fuel and blast shut off and observe how the expansion and compression curves show on the diagram. If they cover each other but do not reach the desired pressure necessary to give positive firing, then the clearance between the piston and cylinder head will have to be reduced. This adjustment will have to be carried out with great care as a small reduction in clearance makes a big difference in the terminal pressure. If the expansion curve falls below the compression curve and the maximum pressure is shown to be below that necessary for firing, one is safe in assuming that the piston rings, exhaust or air inlet valves are leaking. In some engines where the starting air is not automatically shut off when the engine picks up on fuel, a leaking air starting valve may show the expansion curve above the compression curve. Care must be taken to ascertain that there is no lost motion in the indicator gear due to slackness, as this will show the same defects on the diagram as that due to leakage, with this exception, that with slack gear and tight rings and valves the pressure will be observed to be correct on measuring the card.

CHECKING CYLINDER LEAKS.

If the piston rings are leaking badly, the operator soon becomes aware of the fact by the pungent odor of burnt gases, but a cylinder head leaking at the joint sometimes produces the same results. Therefore the best method to employ in locating the source of leakage is as follows: After the engine is shut down, connect up the turning gear to prevent the engine from turning and run blast air into the cylinder by levering open the fuel valve. By listening at the bottom of the cylinder—they are generally open at the bottom—air will be heard escaping if the piston rings are leaking. If the rings are in good condition, disconnect the exhaust pipe between the valve and exhaust manifold. If no signs of leakage are detected here, then do the same with the air inlet valve. With certain makes of engine this procedure is necessary as the cylinder head has to be removed in order to withdraw an exhaust or air inlet valve, so it is best to test them in the manner described.

There are other leaks that do not show on a diagram unless very serious, such as a cracked cylinder head. There are quite a large number of cracked heads in commission, as the crack generally closes up when the engine is running, but the point to guard against is the filling up of the cylinder with water when the engine is stopped and the head, by cooling, opening up the crack. A cracked piston can easily be detected, as the gases leak through the cracks and can be seen emerging from the piston cooling-water discharge pipe.

Fig. 4 shows a diagram taken from a cylinder where the fuel valve was leaking. Faulty timing or too small roller clearance will give somewhat similar results, the general consequences being preignition and an abnormal maximum pressure. This condition usually causes a distinct detonation and should be attended to immediately. Vibration of the engine sometimes causes the adjusting screws on the valve levers to work back, with the result that the valves cannot seat because the rollers bear on the cam all the time. When a valve is seating properly, the spring will be observed to give a sharp tremble. When roller clearances are taken, see that the slack motion between roller and valve is taken up or a false reading will be obtained.

A condition where the cylinder has been primed with oil previous to starting is illustrated in Fig. 5, showing the starting air diagram and the first firing diagram on the same card. This shows the abnormal pressures sometimes obtained due to injudicious priming, and is generally the cause of the relief valves lifting when starting up. Priming should be resorted to

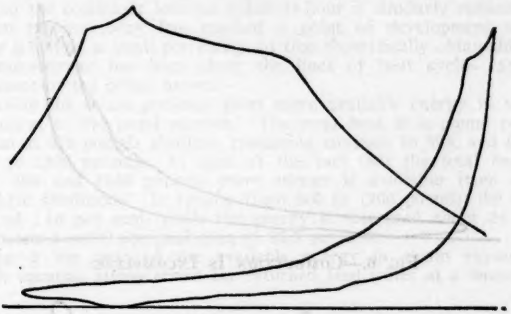


FIG. 4.—DIAGRAM SHOWING LEAKY FUEL VALVE.

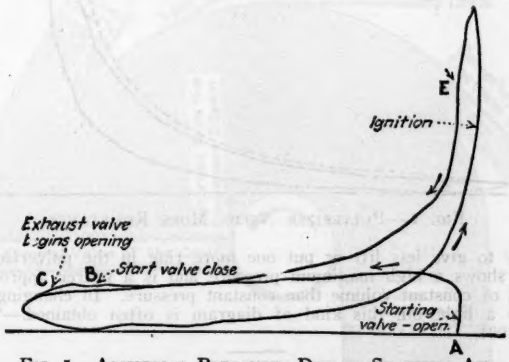


FIG. 5.—ABNORMAL PRESSURES DUE TO STARTING AIR.

with discretion. The writer once saw a relief valve, casing and all, blown clean out due to an overdose of kerosene injected through the indicator cock with a syringe previous to starting up.

A PREVALENT CONDITION.

Fig. 6 shows a wavy combustion line due to incomplete atomization. This was caused by the oil not being sufficiently broken up when entering the cylinder, each lump firing separately and at different periods, causing the pressure to jump up with each explosion. This is also a cause of after burning. Staggering the holes in the pulverizer rings will often cure this

defect without any further alteration. Defects of the combustion line on a diagram are usually noted when changing from one grade of oil to another without altering the pulverizer accordingly.

The result of having the fuel valve with correct opening but too little resistance in the pulverizer, is shown in Fig. 7. To correct this it will be

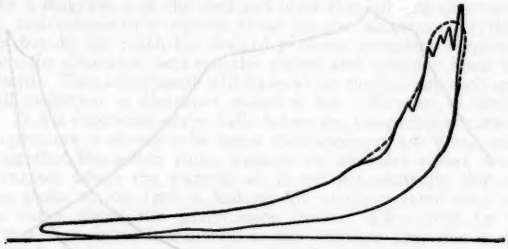


FIG. 6.—COMBUSTION IS INCOMPLETE.

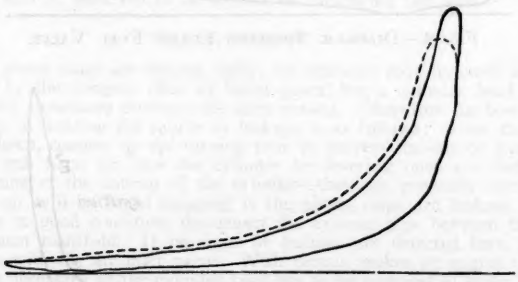


FIG. 7.—PULVERIZER NEEDS MORE RESISTANCE.

necessary to give less lift or put one more ring in the pulverizer. This diagram shows a high maximum pressure and is a nearer approach to a condition of constant volume than constant pressure. In changing from a heavy to a light oil, this kind of diagram is often obtained.—"Power," June 3, 1924.

CONVENIENT ANALYSIS OF MODERN PLANT AND APPLICATION TO SHIP PROPULSION.

Net plant efficiencies with stage bleeding or reheating which may be quickly obtained from simple diagrams with appropriate corrections, are of interest to both land and marine practice.

Conservatism was stressed by Eskil Berg, in addressing the Metropolitan Section of the A.S.M.E. some weeks ago, concerning the advantages of a modern high-pressure steam plant as applied to ship propulsion. In spite of the fact that reheating would prove beneficial, and probably practical as subsequent discussion brought out, this was not included in the 550-pound 750-degree 40,000-K.W. plant for propulsion. The bulky piping characteristic of reheating equipment of the present time, though not a necessity,

might be cited as an objection to the entire scheme. While allowing for heat and electricity, as required for ship use, a shaft horsepower per 0.55-pound of fuel oil is deduced.

The plants of a few years ago delivered a kilowatt with fourteen pounds of steam going to the condenser. With the adoption of high pressure, superheat, reheat and bleeding, this figure can be cut to less than half, which means that the condenser loss per kilowatt-hour is similarly reduced. Since the steam turbine today has reached a point of development where its efficiency is within a small percentage of that theoretically obtainable, power-plant improvement has been along the lines of heat cycles rather than improvement of the prime mover.

Increasing the steam pressure gives more available energy in the course of expansion to the usual vaccum. The total heat in a pound reaches its maximum at 370 pounds absolute, remaining constant to 395, and decreasing slightly to 1200 pounds. In spite of the fact that the total heat lowers between 395 and 1200 pounds, more energy is available from expansion under these conditions. In raising from 200 to 1200 pounds, the total heat is reduced 1.58 per cent, while the energy is increased about 24 per cent, which means a net theoretical gain of 25.5 per cent.

In Fig. 2 the ratio of the available energy in steam expanded to a 28.5-inch vacuum, giving credit for returned feed water at a temperature of

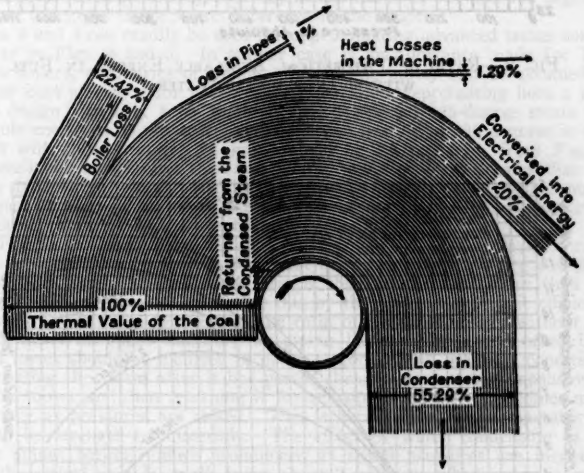


FIG. 1.—TWENTY PER CENT OF ENERGY IS AVAILABLE WITH 250-POUND 200-DEGREE SUPERHEAT STEAM.

90 degrees F., is shown. This represents a perfect prime mover and boiler. Its application to a plant of average steam conditions of 250 pounds 200 degrees superheat is indicated in Fig. 1. Twenty per cent of the value of the coal is converted into electrical energy. This may be derived from Fig. 2, which gives 32.8 per cent with perfect boilers and turbines. By assuming 61 per cent as an over-all plant efficiency for the best conditions, we find that 20 per cent of the power energy is available as electricity.

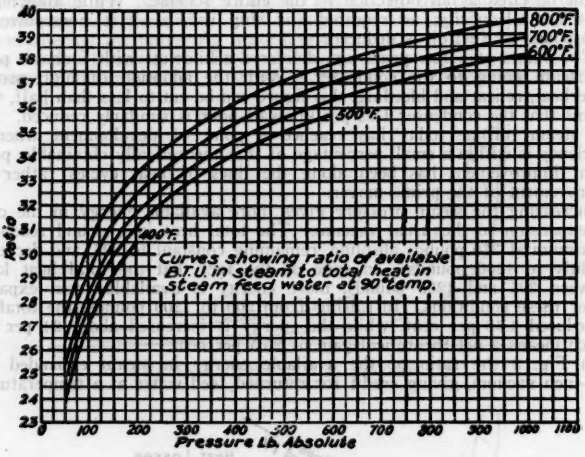


FIG. 2.—RATIO OF THEORETICAL AVAILABLE ENERGY IN FUEL WITH 90 DEGREE FEED WATER.

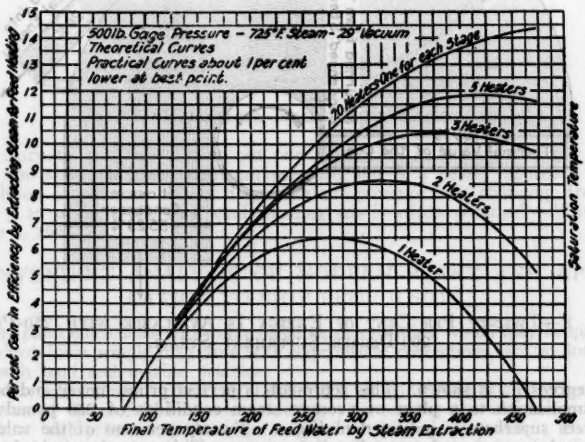

500 lb. Gage Pressure – 725° F. Steam – 29" Vacuum
Theoretical Curves
Practical Curves about 1 per cent lower at best point.
10 Heaters-One for each Stage
5 Heaters
3 Heaters
2 Heaters
1 Heater
Percent Gain in Efficiency by Extracting Steam & Feed Heating
Saturation Temperature
Final Temperature of Feed Water by Steam Extraction

FIG. 3.—EXTRACTION GAIN FIGURED AT 500 POUNDS, STEAM, BUT CORRECT WITHIN 2 PER CENT FROM 200 TO 1000 POUNDS WITH USUAL HEATERS.

The theoretical gains by steam extraction for heaters when bleeding at 1, 2, 3, 5 and 20 stages, are indicated in Fig. 3. These curves are calculated for 500-pound gauge, 725 degrees F., and 29-inch vacuum. They can be used with comparatively small error for other pressures and temperatures. Taken in connection with Fig. 2, a plant using the extraction cycle may be approximated in efficiency by assuming the proper boiler, prime mover and other losses.

If the steam admitted is initially dry and saturated, the gain would be larger than is shown in Fig. 3, by several per cent. If the curves in Fig. 3 are used for 200-pound pressure, 20 heaters, they will read 3 per cent high, but if for only three heaters, 1 per cent, and correspondingly less for fewer heaters. For 1000 pound these are from 3 to 1½ per cent low for the range between 20 and 3 heaters. In practice two to four heaters are ordinarily used, so that Fig. 3 is sufficiently accurate for quick approximation, at ordinary pressures.

Stages for extracting steam are selected in accordance with the temperature range between that of the condensate and the ultimate temperature of the feed water for the boiler. The steps of extraction are usually laid off at equal temperature intervals, as near as possible. The first extraction is ordinarily at 3½ to 4 pound absolute, corresponding to 147 or 153 degrees F. If it is desired to raise this to 300 degrees in three heaters, the remaining 150 would be taken from stages having temperatures of 231 and 306 degrees, allowing 6 degrees temperature difference in the heater.

Figs. 2 and 3 can readily be used for approximating advanced steam conditions as in Figs. 4 and 5. In neither case is an allowance made for loss due to boilers, auxiliaries or piping. The prime mover can be assumed at 76.7 per cent efficiency for purposes of illustration, representing here a tentative design. In Fig. 4 we find that for 350-pound 725-degree steam the available energy is 35 per cent. If feed-water heating to 290 degrees is employed with three heaters, the gain should be 9.8 per cent, from Fig. 3. The available energy ratio therefore would be 9.8 per cent greater than 35, which is 38.5 per cent. Multiplying this by the assumed prime-mover efficiency of 76.7, we find that 29.5 per cent of the energy is available without consideration of boiler, auxiliary or piping losses.

In Fig. 5 we obtain from Fig. 2 for 550-pound 725-degree steam, a ratio of 37 per cent. Feed-water heating with three heaters to 300 degrees gives 10 per cent gain. The ultimate ratio is then 10 per cent more than 37, which is 40.7 per cent. Multiplying this by the prime mover unit efficiency of 76.7, we obtain 31.3 per cent as the ratio of available energy without the consideration of boiler auxiliary or piping losses. These and other incidental losses should be included in order to conform to practical conditions.

Reheating the steam after it has passed through part of the expansion in a prime mover and then returning it for remaining expansion, becomes more necessary as pressures are raised. This is because the final temperature is limited by strength of materials. The effect of water condensing in the lower stages becomes more pronounced as steam pressures are increased. The theoretical gain is small, being about 3 per cent when steam is withdrawn at one-fifth of the initial temperature and reheated to the original, while the decrease in water rate is around 4 per cent due to the reduction of friction losses in the turbine. With losses in piping of 1 per cent, the total gain in practice is about 6 per cent.

Figs. 5 and 6 indicate the gains due to bleeding where reheating is also employed. These refer to 550-pound gauge 725-degree steam and 300-degree feed water. Without reheating, a kilowatt-hour may be obtained with a theoretically perfect boiler, as shown in Fig. 5. In Fig. 6 the reheaters are placed in action, which give up 1128 B.T.U. from the boiler to the turbine. The total gain in this case is 10 per cent due to bleeding and 6 per cent

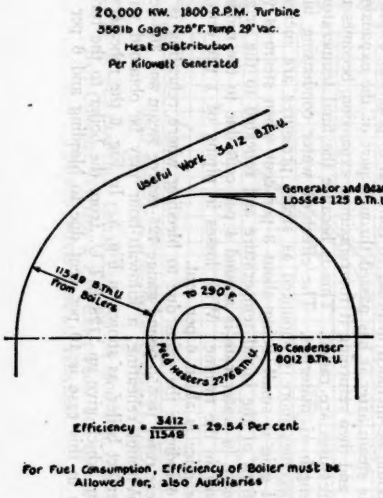

20,000 KW. 1800 R.P.M. Turbine
350lb Gage 725°F. Temp. 29" Vac.
Heat Distribution
Per Kilowatt Generated
Useful Work 3412 B.Th.U.
Generator and Bearing Losses 125 B.Th.U.
11548 B.Th.U. From Boilers
To 290°F.
Feed Heaters 2276 B.Th.U.
To Condenser 6012 B.Th.U.
Efficiency = 3412/11548 = 29.54 Per cent
For Fuel Consumption, Efficiency of Boiler must be Allowed for, also Auxiliaries

FIG. 4.—BLEEDING CYCLE RETURNS HEAT; EFFICIENCY OF BOILER AND PIPING NOT CONSIDERED.

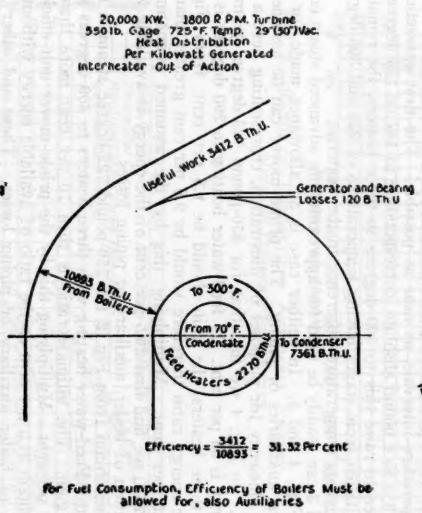

20,000 KW. 1800 R.P.M. Turbine
550 lb. Gage 725°F. Temp. 29"(30") Vac.
Heat Distribution
Per Kilowatt Generated
Interheater Out of Action
Useful Work 3412 B.Th.U.
Generator and Bearing Losses 120 B.Th.U.
10893 B.Th.U. From Boilers
To 300°F.
From 70°F. Condensate
Feed Heaters 2270 B.Th.U.
To Condenser 7561 B.Th.U.
Efficiency = 3412/10893 = 31.32 Per cent
For Fuel Consumption, Efficiency of Boilers Must be allowed for, also Auxiliaries

FIG. 5.—HIGHER PRESSURE AND TEMPERATURE GIVE BETTER EFFICIENCY THAN IN FIG. 4.

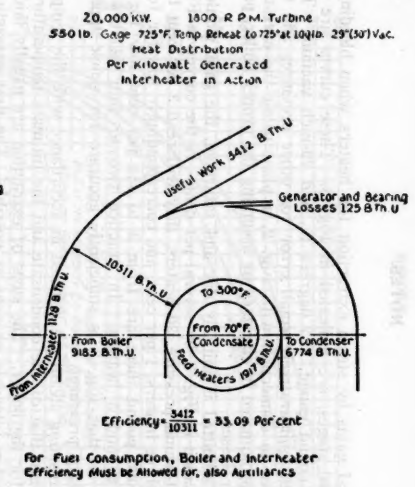

20,000 KW. 1800 R.P.M. Turbine
550 lb. Gage 725°F. Temp. Reheat to 725°at 10%lb. 29"(30") Vac.
Heat Distribution
Per Kilowatt Generated
Interheater in Action
Useful Work 3412 B.Th.U.
Generator and Bearing Losses 125 B.Th.U.
10311 B.Th.U.
From Interheater 1129 B.Th.U.
From Boiler 9183 B.Th.U.
To 300°F.
From 70°F. Condensate
Feed Heaters 1917 B.Th.U.
To Condenser 6774 B.Th.U.
Efficiency = 3412/10311 = 33.09 Per cent
For Fuel Consumption, Boiler and Interheater Efficiency Must be Allowed for, also Auxiliaries

FIG. 6.—REHEATING GIVES 5.5 PER CENT GAIN IN EFFICIENCY OVER THAT IN FIG. 4.

to reheating, which is 16 per cent. Boiler and piping efficiencies should be considered, for further refinement. It will be seen, from Figs. 5 and 6, that the over-all efficiency is increased from 31.32 to 33.09 per cent.

Superheat gives a theoretical gain that is almost negligible as given in Table I. There is, however, a comparatively large gain practically as a result of superheat, which reduces greatly the friction losses in the turbine. Moisture in the steam is a great source of friction loss. The addition of

TABLE I—ACTUAL GAIN BY SUPERHEAT IS GREATER THAN THE THEORETICAL.

Steam conditions, 250 pound to 28½ inch vacuum.

Degrees Superheat.	Temp., Degrees F.	Available Heat.	Corresponding Foot-Pounds.	Total Heat.	Per Cent Increase in Fuel to Produce Superheat.	Per Cent Increase Available Energy Due to Superheat.	Net Theoretical Gain, Per Cent.	Decrease in Water Rate, Per Cent.	Actual Gain, Per Cent.
0	406	369.9	288,000	1,201.1	....	....	....	..	....
50	456	381.4	297,000	1,233	2.66	3.11	.45	4	1.34
100	506	393.5	306,000	1,264	5.25	6.38	1.14	8	2.75
150	556	405.9	316,000	1,292	7.57	9.74	2.17	12	4.43
200	606	418.7	326,000	1,320	9.90	13.22	3.32	16	6.10
250	656	431.8	326,500	1,346	12.08	16.75	4.67	20	7.92
300	706	445.3	347,000	1,374	14.40	20.4	6.00	24	9.6

superheat reduces the moisture greatly and therefore the friction loss. As steam pressures are raised, while temperatures are limited by physical conditions, there is some tendency to decrease superheat. Table II shows the losses in a well-designed turbine for both saturated steam and 200 degrees superheat. It will be seen that the friction loss, which is 20 per cent, and therefore the principal one in the first case, is reduced to 15 per cent by the

TABLE II—SUPERHEAT REDUCES LOSSES IN A WELL-DESIGNED TURBINE.

	Loss, Per Cent	
	Saturated	200 *Deg. F. Superheat*
Loss due to friction in nozzles and blades and windage loss of disks and blades	20	15
Steam-leakage loss	3	3
Rejected energy (due to residual steam velocity)	3	3
Bearings, packing, etc.	1	1
Total loss	27	22
Efficiency of turbine	73 per cent	78 per cent

application of superheat so that the over-all efficiency is increased from 73 to 78 per cent.

A turbine disk operating at about 10 per cent moisture under certain conditions produces twice as much friction as if surrounded by saturated steam. Fig. 7 indicates temperatures throughout a turbine for 265-pound

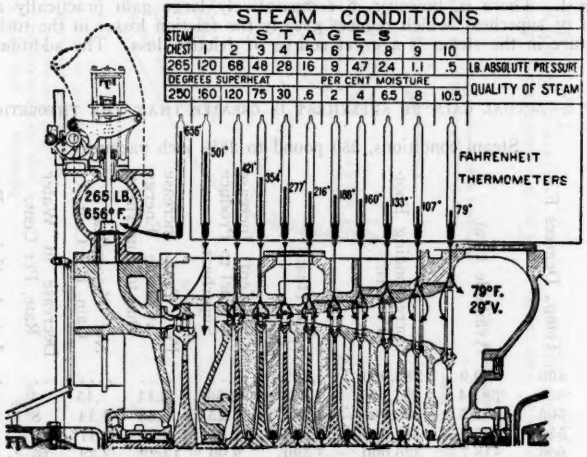


FIG. 7.—SUPERHEAT REDUCES MOISTURE CONSIDERABLY IN LAST SIX STAGES.

steam 250 degree superheat. The moisture in the last stage is 10.5 per cent; without superheat the moisture would be practically doubled. The stage heat conditions are given in Table III.

TABLE III—COMPARING QUALITY OF STEAM IN VARIOUS STAGES WITH DRY INITIAL STEAM AND THAT HAVING 250 DEGREES OF SUPERHEAT.

Stages	1	2	3	4	5	6	7	8	9	10
Quality of steam						Per Cent Moisture				
Dry initially.....	4.4	6.8	8.15	9.8	11.5	13	14.5	16	17.3	18.7
Quality of steam	←—Degrees Superheat—→					←—Per Cent Moisture—→				
250 deg. superheat	160	120	75	30	0.6	2	4	6.5	8	10.5

The ship-propelling equipment would consist of two 20,000-K.W. turbo-generators, two 25,000 shaft horsepower synchronous motors for driving the propeller shafts and two 2,000-K.W. alternating-current motor-generator sets for furnishing power for alternating-current motor-driven auxiliaries. For steering gear, excitation current and other auxiliary direct current power, two 500-K.W. direct current motor-generator sets are provided with one 35-K.W. direct current generator for supplying excitation current to the auxiliary alternating current generator when maneuvering in port.

The propelling turbines operate practically at a base load. The four motor-generator sets would be operated directly from the main power generators, except when maneuvering or in port. Auxiliary attachable turbines and a condenser are supplied for operating under these conditions.

The calculated water rate of the main turbine operating under full power is 8.75 pounds per K.W.-hour. A shaft horsepower should be produced on 6.725 pounds, including motor losses, but not excitation. Alternating-current power is produced at 10.1 pounds per K.W.-hour, and direct current at 10.35.

Steam for feed-water heating and other purposes is extracted in three sets of 20 pounds, 40 pounds, and 75 pounds, respectively. This heats the feed water successively to 220, 260 and 300 degrees F.

The combined boiler, superheater and air-preheater efficiency is taken as 86 per cent. Table IV gives an analysis of calculations indicating fuel

TABLE IV—SUMMARY OF STEAM AND FUEL CONSUMPTION FOR HIGH-SPEED PASSENGER SHIP.

Load on Main Turbine Generator	*K.W.*
Main propelling turbine, 50,000 S.H.P., 97 per cent efficiency	38,500
Auxiliary a.c. motor generator set, 1965.3 K.W., efficiency 86 per cent	2,270
Auxiliary d.c. motor generator set, 465 K.W., 84.5 per cent efficiency	550
Total K.W.	41,320
Steam consumption	pound steam per hour
Main turbine, 41,320 x 8.75	361,550
Steam admitted in lieu of that extracted for feed water, heating of vessel, etc.	43,700
Air ejector	2,500
Total steam consumption	407,750
Pounds steam per S.H.P.-hr., all purposes	8,155
Fuel consumption conditions: Boiler efficiency, 86 per cent; heat value of 1 pound of oil, 19,000 B.T.U.; calculated feed-water temp., 300 degrees F.; relative evaporation from and at 212 degrees	16.838
Factor of evaporation	1.1335
Actual evaporation per pound of fuel oil	14.855
Pounds fuel oil per hour	27.450
Tons of fuel per day	294
Pounds of oil per shaft horsepower	0.55

required for the production of a shaft horsepower. Steam for heating the oil, heating the vessel, cooking, and electricity for all purposes are figured in. The subject of reheating is omitted, as the bulky piping might be considered impracticable aboard ship. The propeller speed is 120 R.P.M.; 3,500 pounds of steam and 675 K.W.-hours of electricity are utilized for ship purposes. Conservative calculation gives 0.55 pound of fuel oil per shaft horsepower, representing a large saving over direct steam drive, as at present.—"Power," July 1, 1924.

VIBRATION IN STEAM TURBINE DISKS.

A valuable contribution to the literature of steam-turbine design was given by Wilfred Campbell, of the General Electric Co., in a paper on "The Protection of Steam Turbine Disk Wheels from Axial Vibration." This paper described the results of an exhaustive investigation which that company made into the various forms of vibration and waves that may be set up in steam-turbine disks, the study having been initiated in consequence of a series of turbine failures extending over a period of several years subsequent to the war. The rapid increase in turbine capacity that took place

at that time was in a large degree accomplished by the use of the larger diameters introduced to give greater bucket speed and by the use of longer buckets. Mechanical possibilities were pushed to the limit from the standpoint of structural strength, and, it soon became evident that most of these failures were due to vibration resulting in fatigue.

Tests were first made of india rubber wheels and then steel disks with which the fluttering action when rotating at high speed was established. Later, by means of sand on stationary wheels placed horizontally and vibrated mechanically, frequencies were determined at which 4, 6, 8, 10 and 12 node vibration would be set up. The higher the number of nodes the higher the frequency of vibration.

Where the natural vibration frequencies of those wheels were determined, the effect of rotating at high speed was studied and it was found to be influenced by the stiffness of the vibrating body and by its mass. The stiffer the wheel or disk the faster it would vibrate, and the greater the mass the slower the vibrations. Increased speed and consequently increased centrifugal force tended to increase the stiffness.

The presence of both stationary and traveling waves was established. It was found that the type of vibration responsible for nearly all the serious failures consisted of a train of backward traveling waves whose backward speed in the wheel exactly equalled the forward speed of rotation of the wheel, resulting in waves stationary in space. The particular speeds of the turbine disk at which this condition would be brought about are characterized as the critical speeds.

A probable cause of stationary waves was found to be a spot or spots of extra pressure, not necessarily more than a few pounds, such as might result from irregularity in the nozzles.

CAUSES OF VIBRATION DETERMINED.

The two general causes of wheel vibration were found to be (*a*) the feathering action of the steam on the buckets and (*b*) pulsating forces which may cause various resonant responses of the wheel. The first type of vibration is eliminated by the use of disks of sufficient thickness so that the energy dissipation during vibration is too great to permit a building up of such a vibration. The second type of vibration is eliminated by building the disks so that resonant frequencies are removed so far from disturbing frequencies in the turbine that vibrations do not occur.

In making these investigations the wheels to be tested or duplicates of those that had failed were placed in a specially constructed housing and by means of a stationary magnet opposite the wheel rim and another magnet on the rotating disk, oscillograph records of the wave progression were obtained.

The company has developed a portable compressed-air-driven vibrator for determining the standing frequencies of wheels in service. Out of 4399 wheels for turbines of over 5000 K.W. installed before March 1, 1924, 3596 have been tested standing, 320 rotated in the wheel-testing machine, 405 tested in the wheel-testing machine, 1683 tested in the customers' plants, 497 wheels replaced to avoid possible trouble and 212 have been tuned for vibration.—"Power," June 10, 1924.

RESEARCH IN HEAT TRANSMISSION.

At the joint session with the American Society of Refrigerating Engineers, a paper on "Research in Heat Transmission" was presented by Dr. Edgar Buckingham, physicist, United States Bureau of Standards, in which the following points were brought out:

Knowledge of heat transfer can be applied not only to such apparatus as evaporators, surface condensers, boilers, etc., in which the object is to attain the maximum heat transfer, but also to insulators ranging from vacuum jackets and granulated cork for low-temperature work, to firebrick and similar refractories at the other end of the scale.

For a given temperature difference the amount of heat passing through a body depends not only upon its thermal conductivity, but also upon the difficulty with which the heat gets into or out of the surfaces from or to the fluids in contact with them. Of these two effects the conductivity of the material is by far the best understood and easiest to deal with.

The transmission of heat between solids and fluids, on the other hand, is extremely complicated. As a result, heat-transfer problems naturally tend to divide themselves into two groups, according to the relative importance of the conductivity and surface effects.

Those concerned mainly with conductivity form a group that can be handled without much difficulty. A good example is found in pipe covering, where the temperature drop from the pipe to the inner surface of the insulation, and from the outer surface of the insulation to the surrounding air, is small in comparison with that through the material. In this case the uncertainties in our knowledge of the surface resistances are made relatively unimportant, while the thermal conductivity of the material, which is here the main thing, can be determined with reasonable reliability in any physical laboratory.

The opposite is true of an ordinary cast-iron steam radiator. Almost the whole of the temperature drop, from the steam inside to the air outside, occurs at two surfaces, mainly at the outer surface, for the conductivity of cast iron is high enough that only a small temperature drop is needed to drive the heat through the iron as fast as it can get away from the outside. If the radiator were replaced by an exactly similar one made of copper, the resistance of the metal and the temperature drop in it would be reduced to about one-sixth, but the temperature drop is already so small that the extra five-sixths thus made available for driving the heat out into the surrounding air would be of very little importance.

Similar remarks might be made about oil coolers, boiler tubes and most types of heat-transfer apparatus in which the heat flows perpendicularly through rather thin metallic walls.

The really important and difficult problems of heat transmission are those dealing with the manner in which heat may get away from a hot surface to a colder space outside, or into a cold surface from a hotter space; namely, by radiation and by convection.

Radiation, varying about as the cube of the absolute temperature, is of the utmost importance in a boiler furnace for example, but is quite negligible in problems of refrigeration engineering. In general, though by no means always, convection is technically more important than radiation. By convection is meant the transportation of heat by motion of the body in which the heat is contained. In the technical application this moving body is nearly always a fluid.

What is demanded of research in technical physics, as distinguished from the very limited experimental investigations which we call tests, is general information that can be used by designers who have to tackle entirely new problems. Small variations from current practice, where test results are already available, can usually be predicted sufficiently well by a combination of common sense and guesswork. But in a large variation, or in an entirely new sort of problem, there is danger of serious mistakes in design unless we have some more general principles to go by and numerical data of a more fundamental nature and more physical significance than are usually obtainable from ordinary performance tests.—"Power," June 10, 1924.

REPAIRING THE *SHENANDOAH*.

Replacing the Nose Cap and Rebuilding the Stabilizing Fin Restore the Naval Dirigible.

By the time this issue is on the newstands, the very serious damage done to the *Shenandoah*, when she was torn loose from her mooring mast early in the year, will have been made good, and she will be once more in service. A recent visit to the Lakehurst Naval Hangar has enabled us to gather additional data regarding the behavior of the ship during the extraordinary wind which swept over the field, and to give the fairly unanimous opinion of her officers as to the succession of events which led to the carrying away of the ship and the partial wrecking of her structure.

It is now established, largely on the testimony of one of the ship's officers who was near the stern of the *Shenandoah*, that the trouble began with the tearing loose of the covering fabric along the edge of the upper stabilizing fin. The four fins are huge affairs and far larger than the layman would imagine when he sees one of these great ships in the air, where the fins are dwarfed by comparison with the vast bulk of the vessel itself. The wrecked fin was about twenty-five feet in height by seventy-five feet in length, and its purpose, in common with the other three, was the twofold one of carrying the vertical and horizontal rudders and providing sufficient area to stabilize the ship and prevent its "rolling," or rotating about its longitudinal axis.

That the covering fabric, if it gave way anywhere, should have begun to tear above the leading edge of the fin, was not unnatural; for it has frequently happened that in high-speed flying planes, the fabric has commenced to tear at the leading edge, particularly when a plane acquired excessive speed when diving to escape or attack an enemy.

When the canvas was ripped at the front of the fin, the blast of wind entered and, exerting great pressure, blew most of the fabric away from the frame, at the same time partially wrecking the metal frame work. As soon as this happened to the upper fin, the great wind pressure on the lower fin began to exert a powerful turning moment, tending to rotate the *Shenandoah* about its longitudinal axis; and this is exactly what happened just before the ship was carried away from the mast, as testified to by the crew who were aboard the ship.

To prevent any heavy torsional stresses in the frame of the ship at the point where her nose is made fast to the mooring mast, the cup-and-cone locking arrangement is provided with ball bearings which, theoretically, should have allowed this rotation of the ship to take place freely. It is believed, however, that this element did not function properly and became more or less jammed. This resulted in a heavy twisting stress on the nose of the ship, which gave way, as we explained in a former issue, immediately abaft the sheet-metal nose cap. It was considered by the staff at Lakehurst, that the conditions of the wreckage showed evidence of "a pull and a twist" at the moment of the disaster. It should be noted, just here, that not far from the mooring mast is a meteorological station where the record shows that the heavy gust which carried the ship away reached a velocity of seventy-two miles per hour.

Prevention of another disaster of the kind is being sought in the direction of an automatic release, which will let go when the pressure exceeds that, due to a wind of a certain maximum velocity; say forty to forty-five miles per hour. Her officers claim it is just as logical for the *Shenandoah* to let slip her moorings in a gale as it is for a ship of the sea to do so in heavy weather and make for the open. They are, of course, the best judges of this; but we are still of the opinion that it would be the part of prudence so to strengthen the bow of the ship that, if the automatic

THIS SHOWS THE BOW OF "SHENANDOAH," WITH THE METAL NOSE CAP, WHICH WAS TORN OUT OF THE SHIP, RIVETED BACK IN PLACE.

release failed to function, or when the ship was exposed to a sudden gust of great violence, there would still be sufficient structural strength at the bow to carry the ship through the emergency without damage. The method of cable reinforcement running back from the bow, which we suggested in our April issue, would be difficult to install; since the apex of the triangular longitudinal members lies at the surface of the hull and not, as we presumed, within it. We believe, however, that the suggestion is worth further consideration by the Construction Corps.

In repairing the *Shenandoah,* the original sheet-metal nose has been rebuilt in place; its connections with the abutting ends of the longitudinal has been reinforced; and special attention has been paid to the re-design of the rotational bearings.

In repairing the broken stabilizing fin, an additional number of light stays has been built in place intermediately with the main A frames. This was done to provide a more complete support for the covering fabric and prevent the violent flapping which, in part, is believed to have been responsible for its being torn loose from the frames. Outside the fractures to the frame work at the bow and stern, there were no other serious injuries to the ship. The gaping holes which appeared under her hull were caused by dropping tanks of gasoline and other weights in order to bring the ship up when she dipped after breaking loose. These holes have been recovered, and the long strips of outer fabric torn from her bow have been replaced. An important change in the ship, however, has been made by removing one of her six motors. The motor, which was installed in the after part of the pilot car, has been taken out and the space allotted to a more powerful radio outfit and accommodations. The weight thus saved will be put into gasoline, and the cruising radius of the ship will thereby be markedly increased. There will be a certain loss of speed when the ship is opened full-out; but the occasions on which maximum possible speed will be called for will be very few; and it is considered that the increase in cruising radius at forty knots is a more valuable military asset than the few knots at maximum speed resulting from the use of six as against five motors.

It is needless to say that the personnel, officers and men alike, are enthusiastic over the virtues of the helium gas with which the *Shenandoah* is inflated, and since the *Shenandoah* is a purely military ship their enthusiasm is well placed. Speaking from a military standpoint, there is no question that the possession by the United States of the only natural source of supply of helium of any magnitude in the whole world, places us in a very strong position in naval and military warfare, so far as lighter-than-air ships are concerned. Helium is an inert gas, that is to say it can neither be set on fire nor exploded. The *Shenandoah* can never be wiped out of existence with the suddenness that marked the loss of the *R*-38, *Dixmude,* or *Roma.* No one, of course, claims that the *Shenandoah* is immune from fire. Any aircraft, whether heavier than air or lighter than air, that is driven by gasoline engines is exposed to grave fire risk, and the *Shenandoah* herself is not exempt; but her officers claim that any fire that started would be comparatively small at the outset and with reasonable watchfulness would be detected and extinguished before it spread. So great is the military advantage conferred by our possession of the only extensive natural sources of helium, that it is considered by some of our aeronautical officers that helium should be pronounced a military asset and restricted, so far as the United States is concerned, strictly to naval and military use. They claim that the sources of supply and the extraction of the gas should be placed exclusively in the hands of the Government, and that its exportation to foreign countries should be prohibited. We think that the point is well made, particularly as the present high cost of helium renders it prohibitive for passenger or freight airship service.

Such prohibition would work no hardship to commercial companies either in the United States or abroad. Its value is of a strictly military character, and the foreign powers would recognize our reservation as an obvious and perfectly just precaution.

At present, with hydrogen costing a few dollars per thousand and helium from 40 to 50 dollars, commercial airship companies are restricted of necessity to the cheaper gas. The lift per 1000 cubic feet under standard atmospheric conditions is, for hydrogen 71.1 pounds, and for helium 65.8 pounds a difference of 5.9 pounds in favor of hydrogen. The gross lift of the *Shenandoah* with helium is 126,800 pounds; fixed weight, 77,450 pounds; net lift, 49,350 pounds. The gross lift with hydrogen is 137,300 pounds and the net lift 59,850 pounds—a gain with hydrogen of 10,500 pounds. With gasoline at six pounds per gallon, and a consumption of .48 pound per horsepower hour, this would mean an increased radius of 945 miles, at cruising speed of 45 miles per hour.

Helium is now cleaned through the extraction of the foreign gases, by refrigeration through the use of liquid air. The foreign gases have a higher temperature of liquefaction than helium, and as this liquefaction point is reached they are successively separated out, leaving the helium in a state of purity.—"Scientific American," July, 1924.

ASSOCIATION NOTES.

The Society held its Annual dinner in Washington, D. C., at the New Willard Hotel on May 17, 1924.

There were present on this occasion about 175 members and guests, among the latter were a number of Senators and Representatives of the Congress.

The President of the Society, Captain J. T. Tompkins, U. S. N., introduced the Toastmaster, Colonel Theodore Roosevelt.

Those present had the pleasure of having introduced by Colonel Roosevelt, The Secretary of the Navy, Curtis D. Wilbur; Senator Robert B. Howell of Nebraska; Congressman William B. Oliver of Alabama, and Mr. Walter M. McFarland. These distinguished speakers each made an interesting talk which it is regretted cannot be printed in the JOURNAL on account of lack of space.

The President of the Society in his closing remarks expressed the appreciation of the Society for the efforts of the Banquet Committee, composed of the following members:

Captain M. E. Reed, U. S. Navy, *Chairman.*
Commander W. A. Smead, U. S. Navy.
Commander H. S. Howard (CC), U. S. Navy.
Commander O. L. Cox, U. S. Navy.
Commander H. Delano, U. S. Navy.
Commander C. S. Root, U. S. Coast Guard.
Mr. A. Conti.
Mr. B. P. Lamberton.
Commander Bryson Bruce, U. S. Navy.

ANNUAL MEETING.

In accordance with the By-Laws of the Society the Annual Meeting for the purpose of making and receiving nominations to offices for the year 1925, and the transaction of such other business as may be presented, will be held at the Navy Department, Washington, D. C., at 4:30 p. m. on the first Tuesday in October, which is October 7, 1924.

Nominations may be made by any Naval Member. They may be made orally in the open meeting or delivered in writing on or before the date of the meeting by a Naval Member not able to be present. The consent of the nominee to accept office, if elected, must be assured. Any member may be placed in nomination for any number of offices for which he is eligible.

QUALIFICATIONS FOR MEMBERSHIP.

The following By-Laws which indicate the kinds of members and qualifications are quoted for the information of those who may not have a copy of the By-Laws at hand:

"Commissioned officers and ex-commissioned officers of the regular Navy, Marine Corps and Coast Guard of the United States shall be eligible as Naval Members. Persons in civil life whose knowledge of engineering is such that they can cooperate with naval engineers in the promotion of professional knowledge may be eligible as Civil Members; they shall be thirty-two years of age, or over, and shall have been in the active practice of an engineering profession for at least ten years and in responsible charge of important work for five years, and shall be qualified to design as well as to direct engineering work. Fulfilling the duties of a professor of engineering who is in charge of a department in a college or school of accepted standing shall be taken as an equivalent to an equal number of years of active practice. Graduation from a school of engineering of recognized standing shall be considered as equivalent to two years of active practice."

"Commissioned officers and ex-commissioned officers of the regular Navy, Marine Corps and Coast Guard of the United States shall be admitted as Naval Members upon application in writing and payment of the annual dues. Civilians who are eligible to civil membership may be admitted upon application in writing and payment of the annual dues, provided that the application is accompanied by the recommendation of two members and provided that the application shall receive the approval of a majority of the Council."

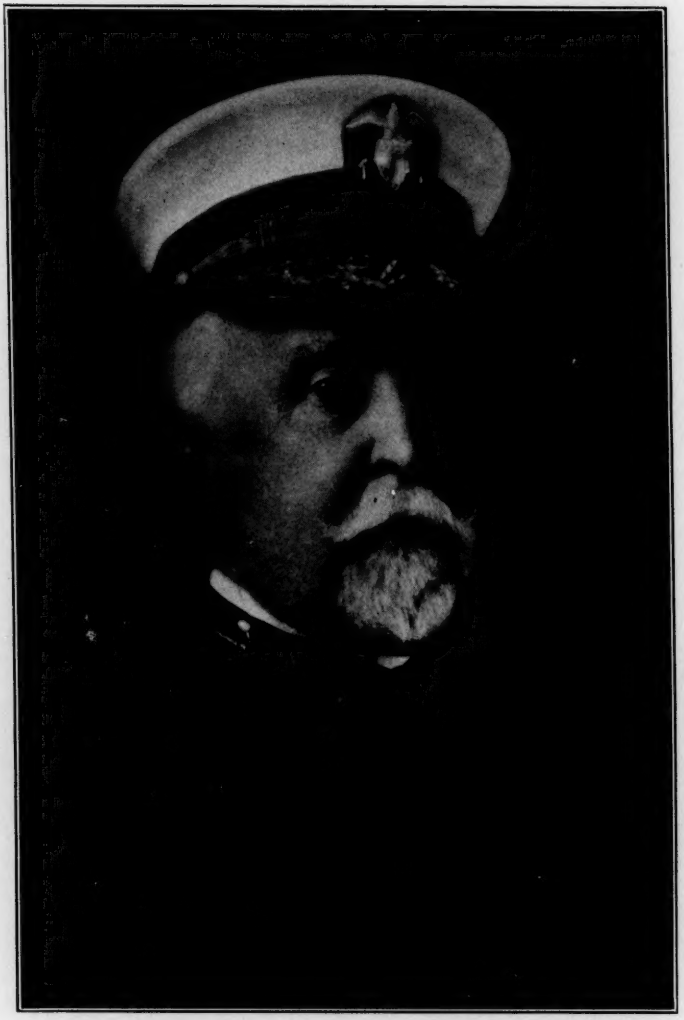
"Persons in civil life who are not eligible for civil membership, but who are especially interested in Naval matters or the Merchant Marine may be eligible as Associates. Commissioned officers of the United States Army and of foreign military and naval services may be eligible as Associates. Commissioned Chief Warrant Officers and Warrant Officers of the United States Navy shall be eligible as Associates."

"Eligibles to Associate Membership may be admitted upon application in writing and payment of the annual dues, provided the application have the recommendation of a member and receive the approval of a majority of the Council, except that in the case of Commissioned Officers of the United States Army and of foreign military and naval services, the recommendation of a member will not be required. Commissioned Chief Warrant Officers and Warrant Officers of the United States Navy shall be admitted as Associates upon application in writing and payment of the annual dues."

"Associates shall be entitled to all the privileges of Members except voting and holding office."

The Secretary-Treasurer would be glad to furnish application blanks to members for friends, or to any person who is interested in becoming a member.

The following members and associates have joined the Society since the publication of the last number of the JOURNAL.



REAR ADMIRAL R. S. GRIFFIN, U. S. NAVY, RETIRED

FORMERLY ENGINEER-IN-CHIEF AND CHIEF OF THE BUREAU OF ENGINEERING, NAVY DEPARTMENT

ROBERT STANISLAUS GRIFFIN.

During this month when Armistice Day serves to focus once more the attention of the World upon the stirring events of the Great War, it is natural, when the part Naval engineering contributed to this great epoch is brought to mind, that Admiral Griffin and his long and distinguished career should stand in the forefront.

Robert Stanislaus Griffin was born in Fredericksburg, Va., September 27, 1857, was appointed to the United States Naval Academy and was graduated as a Cadet Engineer in 1878.

He served in various capacities on shore and afloat during the early years after his graduation, was Engineer Officer of the U. S. S. *Mayflower* during the Spanish American war, later served on the battleships, *Illinois* and *Iowa* and as Fleet Engineer of the North Atlantic Fleet in 1904-5. He was ordered to the Bureau of Engineering, Navy Department in 1905 and served at the Bureau until his retirement from active service. During this period, he was Assistant Chief of the Bureau from 1908-13, and Engineer-in-Chief and Chief of the Bureau of Engineering from May 13, 1913, to the time of his retirement from active service on account of age. This extraordinary service as Engineer-in-Chief covers a period antedating the Great War to well after its conclusion.

Admiral Griffin has always enjoyed the confidence of his superiors and the admiration and respect of all those who were associated with him. The approval of electric propulsion for capital ships of the Navy is one of the outstanding examples of his foresight, progressiveness and readiness to accept responsibility. The honors which have been conferred upon him have been well deserved. He is an Honorary Member of the American Society of Mechanical Engineers, one of the organizers of the American Society of Naval Engineers, its first Secretary-Treasurer and is a Past President and Honorary Member. He has received from Columbia University the Honorary degree of Doctor of Science; from Stevens Institute of Technology the Honorary degree of Doctor of Engineering; was made a Commander of the Legion of Honor by the Republic of France and awarded the Distinguished Service Medal by his own country.

NAVAL MEMBERS.

Brown, Harlie H., Lieutenant, U. S. N.
Crofford, William N., Lieutenant, U. S. N.
Daggett, Roswell B., Lieutenant (CC), U. S. N.
Dean, George S., Lieutenant, U. S. N.
Earle, Fred M., Lieutenant (CC), U. S. N.
Gwathmey, Cabell, Ensign, U. S. N.
Gygax, Felix, Commander, U. S. N.
Harper, Richard H., 344 Park Avenue, Worcester, Mass.
Hudson, Lester J., Lieutenant, U. S. N.
Hykes, John H., Lieutenant, U. S. N.
Kelly, Richmond K., Lieutenant (CC), U. S. N.
Lamb, Scott G., Lieutenant, U. S. N.
Lovejoy, Ralph L., Lieutenant, U. S. N.
McBride, Lewis B., Captain (CC), U. S. N.
McClendon, William E., Lieutenant, U. S. N.
Mewshaw, Harry A., Lieutenant, U. S. N.
Mills, Earle W., Lieutenant, U. S. N.
Pixton, John E., Lieutenant, U. S. N.
Rend, Charles J., Lieutenant, U. S. N.
Ross, Charles C., Lieutenant Commander, U. S. N.
Smith, Francis A., Lieutenant, U. S. N.
Walling, Frederick T., Lieutenant, U. S. N.
Welles, Radcliffe C., Lieutenant, U. S. N.
Wicks, Zeno W., Lieutenant, U. S. N.
Winn, J. Greeley, Lieutenant, U. S. N.

ASSOCIATE MEMBERS.

Beck, Charles Cameron, Fort Warren, Boston, Mass.
Boeckel, W. J., 730 Munsey Building, Baltimore, Md.
Coppus, Frans H. C., President Coppus Engineering Corporation, 344 Park Avenue, Worcester, Mass.
Igartua, Luis A., Engineering Lieutenant, Argentine Navy.
Kedinger, Nicholas, Chief Machinist, U. S. N.
Parduhn, Franz J. M., Chief Machinist, U. S. N.